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CONTENTS

	Page
Survey of Damage by Carrot Fly on Carrots in England and Wales, 1946–50	69
Control of Nectria Eye-rot of Apple by an Eradicant Fungicide. *R. Eric Taylor and R. J. W. Byrde*	72
An Aphid Counting Grid. *A. H. Strickland*	73
Sampling Cabbage Aphid Populations on Brussels Sprouts. *B. M. Church and A. H. Strickland*	76
Control of Cabbage Root Fly in the Seedbed. *T. Rosborough*	81
Effect of Downy Mildew on Yield of Sugar Beet. *C. E. Cornford*	82
New Records of Legume Virus Diseases in England. *Patricia J. Klesser*	84
Napomyza lateralis (Fall.) : a New Pest of Calendulas. *H. G. Morgan*	85
Springtail Damage to Tomatoes. *E. B. Brown*	87
Further Observations on Delayed Sporulation of *Phytophthora Infestans* on Infected Potato Shoots. *Margaret A. Keay*	88
Trials of Substitutes for Sulphuric Acid for Potato Haulm Killing, 1952 and 1953	90
Carrot Fly Injury and "Canker" of Parsnips in the West Midlands. *C. A. Collingwood and H. E. Croxall*	99
The Weather of England and Wales : Autumn and Winter, 1953–54	105
New or Uncommon Plant Diseases	105
Bulb Scale Mite on Narcissus	106

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SURVEY OF DAMAGE BY CARROT FLY ON CARROTS IN ENGLAND AND WALES, 1946-50

Contribution from the Conference of Entomologists, National Agricultural Advisory Service, compiled by E. B. Brown, N.A.A.S., Cambridge

When work on the assessment of damage by insect pests was started in 1945, the Carrot fly, *Psila rosae* F., was one of the insects chosen for study. Some preliminary observations were made in 1946, when counts of clean, slightly damaged, and severely damaged carrots were carried out in a number of field or market-garden crops in each province. Estimates of damage by larvae of the first and second generation flies were made in July and October respectively. The most rapid deterioration of attacked carrots was found to occur in late autumn, so that counts made in October proved to be too early for a proper assessment of the damage caused by flies of the second generation.

In 1947, and subsequently, counts of damaged carrots were arranged in July and November to coincide roughly with the damage done by the two generations of the fly. April and earlier sown crops were examined in the second half of July for the first generation attack, and May and later sown crops in the first half of November for the second generation. Carrots usually suffer the heaviest damage on the headlands, the attack quickly diminishing in severity towards the centre of the crop. The sampling method was based on the work of Wright and Ashby (1946). The method for field crops was a compromise between the headland and midfield sampling technique of these workers, and consisted in taking 100 roots in groups of three from a line around the field at a distance of twenty yards from the hedge or ditch. Where no field crops were available, counts were made in carrots grown on a market-garden scale and, as under such conditions the attack is likely to be more uniform, the method adopted was to examine 100 roots in groups of three from a diagonal across the crop. The aim was to cover a minimum of five fields in each province each year, except in 1949 and 1950, when, if possible, ten fields were to be examined. These were to be situated in carrot-growing areas, and if possible on the same farms each year, choosing large fields for the field-scale sampling. Four provinces participated in the field-scale sampling and five in the small-scale work.

The carrots were washed and graded into three categories: "clean", "slightly attacked" and "unmarketable". The exact definition of an "unmarketable" carrot varied to a slight extent over the survey period. At first, a carrot with three or more deep mines was classified as unmarketable, but from November 1949 the carrots in this category had one-third or more of their surface area affected.

DIFFICULTIES ENCOUNTERED IN THE SURVEY

In 1949, it became common practice to spray seedling carrots with paraffin for weed control, and it was thought by farmers that some control of Carrot fly was also resulting from this treatment. In an experiment, Wright (1951) did not obtain positive results with a paraffin spray against the pest, but in the 1950 survey, seven fields sprayed with paraffin gave an average of 81·7 per cent of clean roots, as compared with an average of 68·2 per cent in thirteen unsprayed fields. This difference is noteworthy. In addition, in the early years of the survey the practice of spraying round headlands and the edges of carrot crops with a sodium fluoride bait for the control of the fly was being replaced by the use of a DDT insecticide. As the results of this treatment were seen to be very good,

more and more fields were sprayed, and in 1949 and 1950 it became difficult to find the unsprayed fields necessary for damage assessment work. The 1949 work was further handicapped by many failures of carrots at the seedling stage. These were probably due to a combination of factors, including both Carrot fly damage and drought. The part played by the fly at the seedling stage could not, of course, be assessed by sampling at the specified dates in July and November.

The degree of shelter for the flies on the edges of the fields was studied in the survey from 1948 onwards, and although the information was difficult to assess, there was some evidence that the amount of shelter was affecting the extent of the Carrot fly attack. When fields were visited in November it was often impossible to say with certainty what shelter had been present during the summer.

TABLE 1

CARROT FLY DAMAGE IN FIELD CROPS, 1947–50

Province	Year	No. of Crops	Mean percentage of Roots		
			Clean	*Slightly Attacked*	*Unmarketable*
(*a*) Early-sown crops sampled in July					
Yorkshire and Lancashire.. ..	1947	5	76·4 (60–88)*	19·6	4·0
	1948	6	79·8 (67–99)	11·5	8·7
	1949	5	99·4 (98–100)	0·6	nil
	1950	5	84·8 (74–95)	12·2	3·0
Eastern	1947	5	98·0 (97–100)	2·0	nil
	1948	5	88·8 (64–100)	9·6	1·6
	1949	10	77·0 (46–97)	21·9	1·1
	1950	9	99·6 (98–100)	0·4	nil
West Midland	1947	5	85·4 (79–90)	15·6	nil
	1948	2	92·5 (87–98)	6·5	1·0
	1949	1	74·0 —	16·0	nil
	1950	6	89·5 (82–100)	10·5	nil
East Midland	1947	3	90·6 (84–95)	6·7	2·7
	1948	3	91·7 (78–100)	2·7	5·6
	1949	5	76·0 (54–92)	23·0	1·0
(*b*) Late-sown crops sampled in November					
Yorkshire and Lancashire.. ..	1947	5	44·4 (29–62)	36·2	19·4
	1948	5	42·3 (15–67)	26·1	31·6
	1949	11	40·8 (19–73)	25·7	33·5
	1950	5	55·4 (28–74)	28·8	15·8
Eastern	1947	6	77·1 (47–95)	18·9	4·0
	1948	5	74·0 (57–81)	23·0	3·0
	1949	10	70·8 (25–93)	18·6	10·6
	1950	4	70·5 (55–84)	27·3	2·2
West Midland	1947	2	39·5 (20–59)	29·0	31·5
	1948	3	66·7 (37–99)	16·7	16·6
	1949	9	86·9 (62–97)	11·6	1·3
	1950	6	92·6 (84–100)	7·4	nil
East Midland	1947	8	54·5 (30–74)	31·0	14·5
	1948	7	53·9 (26–76)	33·3	12·8
	1949	6	70·3 (55–82)	23·5	6·2
	1950	7	76·1 (50–94)	22·5	1·4

* Figures in brackets give the lowest and highest percentages of clean roots found in the several fields examined.

Survey of Damage by Carrot Fly

Records on Field Crops

Over half the carrot acreage of the country is made up of field crops in the Eastern Province. Field crops in the East Midland, West Midland and Yorkshire and Lancashire Provinces account for another third of the acreage. In this summary of the survey, therefore, results on field crops only are given. Table 1 shows the average percentages of clean, slightly attacked, and unmarketable carrots for all fields examined in each province each year. The variation from field to field within the provinces is indicated by the range from lowest to highest percentage of clean roots.

The number of fields examined was not large enough, and the variation within provinces was too great, to permit the extraction of any mean figures for the comparison of the damage in the different seasons or for the country as a whole. The results provide some indication, however, of the seriousness of Carrot fly as a pest. In the Yorkshire and Lancashire Province, for example, it is quite evident that damage in maincrop carrots during November can be very considerable. In the samples from the twenty-six fields examined from 1947 to 1950, there was an average of 25 per cent of the carrots unmarketable.

The sowing date was recorded for each field examined, and the results of the July and November samplings, in relation to month of sowing, are shown below.

Table 2

Influence of Date of Sowing on Severity of Carrot Fly Attack, 1947–50

Month of Sowing	Early-sown Crops Sampled in July				Late-sown Crops Sampled in November			
	No. of Crops	Mean Percentage of Roots			No. of Crops	Mean Percentage of Roots		
		Clean	*Slightly Attacked*	*Unmarketable*		*Clean*	*Slightly Attacked*	*Unmarketable*
January ..	1	98·0	2·0	nil	—	—	—	—
February ..	3	68·4	28·3	3·3	—	—	—	—
March ..	25	89·4	9·2	1·4	3	68·0	19·7	12·3
April ..	34	89·6	8·3	2·1	16	52·0	25·4	22·6
May ..	12	88·1	9·7	2·2	58	67·1	24·0	8·9
June ..	1	100·0	nil	nil	29	75·8	15·6	8·6
July ..	—	—	—	—	6	82·3	15·0	2·7
August ..	—	—	—	—	1	87·0	13·0	nil

Except for the mid-months, there were too few crops to permit the drawing of any firm conclusions. For maincrop carrots, however, it would appear that the later the sowing the cleaner the crop, and this is in keeping with the experience of many farmers.

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CONTROL OF NECTRIA EYE-ROT OF APPLE BY AN ERADICANT FUNGICIDE

by R. ERIC TAYLOR

National Agricultural Advisory Service, Evesham

AND R. J. W. BYRDE

Long Ashton Research Station

It was shown by Byrde, Crowdy and Roach (1952) that cankers of *Nectria galligena* Bres. on apple shoots and branches sprayed in autumn or spring with 0·3 per cent phenyl mercury chloride produced few or no spores during the succeeding eighteen months. This decrease in the supply of inoculum much reduced the subsequent incidence of leaf scar infections on the sprayed trees. As fruiting *Nectria* cankers also provide the source of spores for eye-rot infections on the fruits, it seemed possible that the frequency of such fruit infections might also be reduced by using a dormant-stage spray to check sporulation on a cankered tree. The eye-rot phase of the disease is particularly common on Worcester Pearmain.

Accordingly, on March 12, 1953, 40 gallons of an eradicant fungicidal spray containing 0·3 per cent phenyl mercury chloride were applied to a block of twelve Worcester Pearmain bush trees in a Herefordshire plantation known to be subject to the disease. On August 12, 1953, about ten days before harvest, the incidence of *Nectria* eye-rot was assessed by recording the number of infected fruits—readily detected by their high colour—in a random sample of 100 fruits per tree. Twelve unsprayed trees adjacent to the treated block were also assessed, to serve as controls. The mean results obtained were as follows :

	Infected Fruit *per cent*
Trees sprayed with phenyl mercury chloride ..	0·17
Control trees unsprayed	2·83

Counts of the total number of infected fruits per tree confirmed the marked effect of the treatment.

Although these results are of limited practical application, owing to the high cost of the treatment, they indicate the possibility of using other eradicant fungicides against this phase of the disease. Furthermore, the sharp contrast in the levels of fruit infection in the treated block and the adjacent trees confirms earlier observations that the conidia are not carried more than 30 feet from a canker and are dispersed by rain, rather than by wind (Munson, 1939).

We thank Mr. J. Morton, owner of the plantation, and Dr. B. F. G. Levy of the N.A.A.S., Herefordshire, for their co-operation.

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AN APHID COUNTING GRID

by A. H. STRICKLAND

Plant Pathology Laboratory, Harpenden, Herts

Early in 1951, the Pest Assessment Committee of the N.A.A.S. Conference of Advisory Entomologists decided to attempt the accurate assessment of Cabbage aphid (*Brevicoryne brassicae* L.) populations in relation to yield reduction in commercial Brussels sprout crops at a number of centres in England and Wales. Preliminary work on methods of sampling Cabbage aphid infestations was carried out during the 1951 season and it soon became clear that a field sample which would detect a doubling of the aphid population as statistically significant would involve the visual counting of large numbers of aphids in the laboratory. Further, since a large number of samples had to be examined from each field site, it was essential that the time spent on counting aphids should be reduced to a minimum consistent with a reasonably reliable estimate of the total number present in each field sample.

Taking into account the probable accuracy of the field sampling method (described elsewhere in this issue), it was decided that an aphid counting method which would give an estimate of the total number of aphids sampled with a standard error of 10–12 per cent would be satisfactory.

First, volumetric methods were investigated. Aphid samples of known composition were made up in 95 per cent alcohol, poured into a graduated measuring cylinder, and allowed to settle for five minutes. The volume taken up by the settled aphids was then read off. This method gave results in terms of cubic centimetres of aphids, but it was obvious that such a figure would be difficult to interpret. For instance, it was found that 2,500 small nymphs, 600 third instar nymphs, and 250 adult apterae all took up the same volume (1·0 c.c.), but it was clearly not safe to assume that these three populations would all have the same effect on the vigour of the host plant. Further, it was found that the composition of the field samples varied from week to week so that it was not possible to assume even an approximately constant proportion of nymphs, adult apterae, and alatae and so convert volumes into numbers of aphids, or any other index figure which would indicate the extent to which the aphids were attacking their host plants.

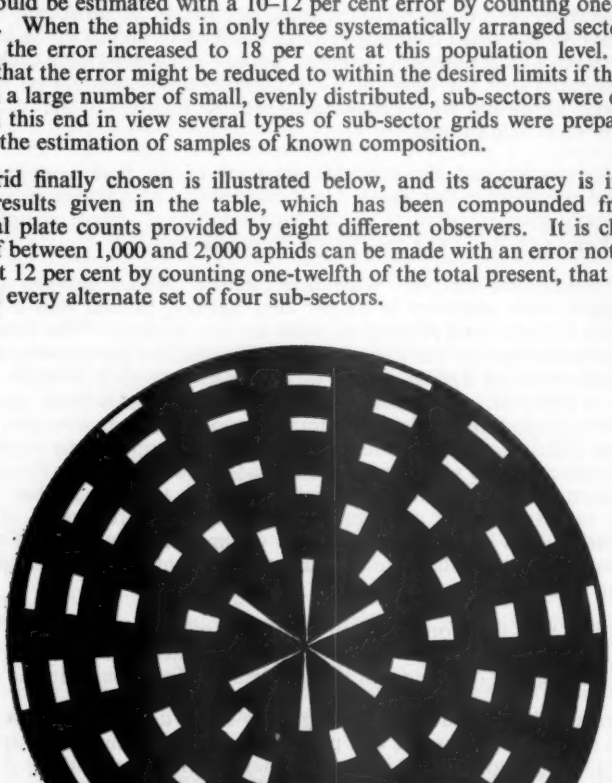
Attention was therefore directed to the possibility of counting a known proportion of each sample by means of a grid, and thereby obtaining an estimate of the total number of aphids (of different stages if necessary) in the sample.

A circular grid was made by drawing thirty-six 10 degree sectors on a piece of card the size of a standard 12 cm. petri dish. Known numbers of aphids were placed in 95 per cent alcohol in a set of these petri dishes, and the dishes were tilted gently from side to side until the aphids were fairly evenly distributed. Each dish was then placed on the grid and the aphids falling in each of the sectors were counted. From a series of twenty-three such dishes, containing a range of from 100 to 6,000 aphids, it was apparent that a sub-sample of six randomly distributed sectors gave an estimate with a considerably higher standard error than a sub-sample of six systematically arranged sectors. There was also an indication that the aphids falling in nine systematically arranged sectors would have to be counted if less than about 1,000 were present, and that the aphids in six such sectors would be sufficient if rather more than 1,000 were present.

There were several disadvantages to this method. Two separate grids were required if populations smaller than, and exceeding, 1,000 were to be counted with equal precision but without unnecessary work ; it was often difficult to count the aphids accurately against a white card background through the thickness of a petri dish ; and it was very difficult accurately to count the aphids in one complete 10 degree sector when large numbers were present.

Subsequent work was based on the fact that aphids were distributed as evenly as possible over the dishes by tilting before being placed on the grid, and the fact that the average sample prepared for counting contained rather more than 1,000 aphids. Work with the sector grid had indicated that populations of over 1,000 aphids could be estimated with a 10–12 per cent error by counting one-sixth of the total. When the aphids in only three systematically arranged sectors were counted, the error increased to 18 per cent at this population level. It was thought that the error might be reduced to within the desired limits if the aphids falling in a large number of small, evenly distributed, sub-sectors were counted, and with this end in view several types of sub-sector grids were prepared and used for the estimation of samples of known composition.

The grid finally chosen is illustrated below, and its accuracy is indicated by the results given in the table, which has been compounded from 160 individual plate counts provided by eight different observers. It is clear that counts of between 1,000 and 2,000 aphids can be made with an error not exceeding about 12 per cent by counting one-twelfth of the total present, that is, those falling in every alternate set of four sub-sectors.



Sub-sector aphid counting grid. Six 10° sectors are each split up into 12 sub-sectors of equal area, and " whirled " anti-clockwise.

MEAN PERCENTAGE STANDARD ERRORS FOR ESTIMATES OF TOTAL APHIDS PER DISH

Type of Grid	Estimated Total Aphids per Dish					
	−500	−1,000	−2,000	−3,000	−4,000	+4,000
Six 10° sectors taken at random	28·9	19·8	15·9	—	—	—
Six 10° sectors arranged systematically..	14·4	11·5	7·9	—	—	—
Sub-sector grid ; aphids in all 18 groups of four sub-sectors counted	15·3	11·2	8·4	5·4	—	—
Sub-sector grid ; aphids in alternate nine groups of four sub-sectors counted ..	—	—	12·3	12·7	9·6	7·6

There is some evidence to show that the accuracy of the sub-sector grid varies slightly according to the observer. For example, my own results for six samples of between 2,000 and 3,000 aphids gave a mean standard error of 6·2 per cent, whereas another observer's results for a very similar set of samples gave an error of 4·4 per cent. Similarly, the latter observer produced results with an overall error of 7·7 per cent for seven samples of between 500 and 2,000 aphids, whereas a third observer's error for a similar set was 11·5 per cent. In this connection it should be noted that the 10 degree sector grid results given in the table are from my own counts only, and are not means obtained by several independent observers.

Essentially, the sub-sector grid consists of six 10 degree sectors " whirled " anti-clockwise into twelve sub-sectors of equal area, each sub-sector being separated from its neighbour by twice its own area, so that four sub-sectors lie along any one 10 degree sector. This standard grid is photographed, and enlarged on celluloid film the same size as a 15 cm. petri dish. The film is then sandwiched between two sheets of thin glass, bound with transparent tape, and fitted to a small light-table illuminated by a 25 watt " pearl " electric light bulb.

In using the grid the observer should take care to include all those aphids which overlap the left-hand and outer margins of the sub-sectors, ignoring those on the right-hand and inner margins. It is important to look straight down at the grid whilst counting, and equally important not to disturb the aphids once a count is in progress.

In the Cabbage aphid population work, individual samples have contained as many as 25,000–30,000 aphids. With large samples of this type the population estimate is arrived at by a combination of volumetric and grid methods. After washing from the sample of brassica leaves, the aphids are shaken up in fresh 95–98 per cent alcohol and allowed to settle. After a few minutes cast skins and parasitized " mummies " can be decanted off, and the aphids poured into a measuring cylinder. After not more than five minutes settling the volume of aphids should be noted. A part of the aphid sample is then poured into a petri dish and prepared for counting, the volume of aphids remaining in the measuring cylinder being noted again after a further settling period. It is then a simple matter to estimate the number of aphids in the complete sample.

The data in the table have been computed from results provided by C. J. Banks and G. Heathcote (Rothamsted Experimental Station), K. S. George (Agricultural Research Council), A. Ibbotson, W. I. St. G. Light, S. W. H. Rolfe, and Miss M. E. John (National Agricultural Advisory Service). I would also like to thank B. M. Church and M. J. Healy (Rothamsted Experimental Station) for a method of estimating the variance of a sub-sector count when the total number of aphids in a dish is not known.

SAMPLING CABBAGE APHID POPULATIONS ON BRUSSELS SPROUTS

by B. M. CHURCH

Rothamsted Experimental Station, Harpenden, Herts

AND A. H. STRICKLAND

Plant Pathology Laboratory, Harpenden, Herts

A routine reconnaissance survey of Cabbage aphid (*Brevicoryne brassicae* (L.)) populations on commercial Brussels sprout crops was started in 1946 by the entomologists in the National Agricultural Advisory Service. Twenty-five plants were examined every October in a diagonal across each surveyed field and were classified by the surveyors according to a visual estimate of the degree of infestation. The same fields were visited again the following January, and actual counts of live aphids and eggs were made on ten plants in each field (Empson, 1952).

In 1951 it was decided to carry out field experiments on Cabbage aphid populations in relation to yield loss in commercial Brussels sprout crops. So far as could be ascertained, only one attempt had been made before 1951 to assess cabbage aphid populations on a field scale (Greaves and Venables, 1950) and on this occasion individual cabbage plants were assigned on examination to one or other of five population classes. It was therefore necessary to evolve a method for obtaining estimates of actual aphid populations, and a series of investigations was carried out in 1951 and 1952 with this end in view.

VISUAL COUNTING IN THE FIELD

The Cabbage aphid rarely reaches pest proportions in England and Wales until the middle or end of July, and by the middle of November the numbers of live aphids per plant have usually dropped to a low level. The problem was therefore to devise a method for sampling during the four summer and autumn months, when the aphids reproduce quickly and fairly large fluctuations in population occur from week to week.

It was known that a reasonably accurate estimate of the numbers of aphids per plant could be obtained by visual counting on the host plant in the field, provided not more than about a hundred aphids were present. An investigation was undertaken to see whether it would be practicable to make visual estimates of aphids on plants with heavy infestations. Six observers were asked to estimate visually the number of aphids on heavily infested plants during the population peak in September 1951. The plants were then uprooted and sent to the Plant Pathology Laboratory, where they were dissected and the aphids were washed off and counted. To avoid bias through reproduction in transit, the aphids were killed by packing the plants in air-tight boxes with cotton wool soaked in methyl-*iso*-butyl ketone. Some typical results are set out in Table 1.

The tendency on the part of all six of the observers who co-operated in this experiment was to underestimate the number of aphids on a plant when more than one or two hundred were present, usually by about 50–60 per cent, but often by far more for heavily infested plants. It was clear that plant examination in the field was not giving an accurate estimate of population density or, indeed, an estimate which could easily be corrected for observer bias.

TABLE 1

SOME VISUAL FIELD ESTIMATES, AND ACTUAL NUMBERS, OF APHIDS ON MATURE PLANTS

Field Estimate (1)	Actual Number from Laboratory Dissection and Examination (2)	Ratio (2)/(1)
250	850	3·4
250	520	2·1
500	720	1·4
600	2,100	3·5
600	1,240	2·1
1,000	1,160	1·2
1,500	3,030	2·0
1,900	3,800	2·0
3,000	14,300	4·9
3,050	19,990	6·5
4,500	19,990	4·4
5,200	12,200	2·4

Attention was therefore directed to the possibility of sub-sampling individual plants in the field, removing the aphids by a washing technique, and counting them in the laboratory.

THE " THREE-LEAF " METHOD

From the end of July, and until the bottom leaves are removed in the normal course of sprout picking, the average Brussels sprout plant carries about thirty mature, or maturing leaves, and ten immature leaves curled tightly in the crown of the plant. Since, at this growth stage, only the outermost of the leaves in the crown are commonly infested with aphids (the greater part of the population being on the middle and lower leaves) it is reasonable to assume that each plant carries about thirty leaves likely to be infested by aphids. It was suggested that three leaves should be taken at random from each sampled plant, giving roughly a 10 per cent sample of the plant material. This suggestion was discussed with D. W. Wright (National Vegetable Research Station) and it was agreed that one leaf should be taken from the outer crown leaves, the second from the mature leaves around the middle of the plant, and the third from the leaves near the base of the plant that were beginning to senesce ; in practice, approximately every tenth leaf.

The limitations of this type of sampling have been discussed by Anscombe (1948) with reference to potato aphids. Bradley (1952) discusses the sampling of potato aphids in relation to leaf area. In the present work it was found that the numbers of aphids per leaf on the crown and middle leaves were roughly equal until mid-August. After this time, numbers on crown leaves decreased and numbers on bottom leaves increased to equal those on the middle leaves. By the end of September the greater part of the aphid population was found on the bottom leaves.

As a result of these changes in the distribution of aphids on the plants, estimates of population changes given by the three-leaf sampling method may be biased. For routine sampling, however, the method has the advantage of simplicity, and any bias will be trivial compared with the large changes in population which occur.

To test the three-leaf sampling method a number of plants were uprooted in September 1951, and three-leaf samples were taken until the plants were stripped.

Each plant produced eight to ten such samples with a small residue of leaves at the base. The samples were washed individually and the aphids were counted. The residuum of leaves and the stem and developing sprouts were similarly examined. These data indicated the accuracy of the estimate of aphid density on a plant obtained from a three-leaf sample, and also showed that approximately 95 per cent of the aphids infesting a sprout plant at this time were on the leaves, the balance being on the stem or the developing sprouts.

Subsequently, five commercial fields of sprouts in Bedfordshire and Essex were sampled using a slightly different method. Fifty plants were selected at random in a traverse across each field, and two outer crown leaves, two middle leaves, and two lower leaves, were taken at random from each. The two sets of one crown, middle, and lower leaf were put into separate envelopes, and the 100 envelopes from each field were brought back to the laboratory, where the aphids were washed off and counted. The results of this two-stage sampling are given in Table 2.

TABLE 2

ESTIMATES OF SAMPLING VARIANCE OF THE THREE-LEAF METHOD FOR EACH OF FIVE FIELDS

Mean Number of Aphids per Three-leaf Sample	Mean Squares for Log : (N+1) Aphids per Three-leaf Sample	
	Between Plants (49 *d.f.*)	*Within Plants* (50 *d.f.*)
40	0·42	0·15
54	0·31	0·45
84	0·33	0·20
170	1·08	0·22
238	0·96	0·40
Average values	0·62	0·28
Expected values of mean squares	$2\sigma_2^2 + \sigma_1^2$	σ_1^2

The table gives the mean number of aphids per three-leaf sample, together with an analysis of variance of the transformed log : (N + 1) data for each of the five fields. As might be expected, the aphids were more evenly distributed in some fields than in others and there are real differences between the variances within the five fields. However, the average value of 0·28 for the within-plant variance can probably be taken as representative over a wide range of populations.

TABLE 3

ESTIMATES OF SAMPLING VARIANCE OF THE THREE-LEAF METHOD WITHIN PLOTS IN A FIELD

	Mean Number of Aphids per Three-leaf Sample					
	<1	1–5	6–10	11–20	21–100	100+
Between plants mean square.. (Three leaves from each plant)	0·12	0·43	0·52	0·61	0·45	0·27
Degrees of freedom	135	270	165	150	90	75

The data in Table 3 were obtained from a series of observations from 25 experimental plots (each of 64 plants arranged in two rows) in a randomized block layout within a commercial sprout crop. They show that the logarithmic transformation makes the variance largely independent of the mean, although it is smallest for very small and very large average counts. Comparison with Table 2 suggests that the variability within plots of this size is of much the same order for counts in the 21–100 range as that found when sampling from a 10–20 acre field, though it is substantially smaller for the very high counts.

In four out of the five fields on which double samples were taken there was significantly more variation in aphid density between plants than between different three-leaf samples from the same plant. It follows that a more accurate estimate of field population is obtained for a given amount of material examined if each plant is sub-sampled rather than examined as a whole. The advantage gained by sub-sampling will differ from field to field, and is probably greatest for fields with moderate to heavy infestations. The data of Table 2 suggest that if a three-leaf sample is about a tenth of a plant, the field population will be determined as accurately by taking single three-leaf samples from a number of plants at random as by the examination of about four times as much material in the form of whole plants*. The practical advantage of sub-sampling is even greater. Careful examination of a heavily infested plant in the field may take 20 minutes or more, and even then give an unreliable estimate, while the complete stripping or removal of whole plants would not be generally permitted in a commercial crop. Taking three-leaf samples from fifty plants in a field, washing the bulked sample and counting the aphids (using the counting grid described on pp. 73–5 of this JOURNAL (Strickland, 1954) involves about 1½ hours work, compared with the 4 hours needed for visual examination of twenty-five moderately infested plants in the field.

The sampling variance of the three-leaf method ($\sigma_1^2 + \sigma_2^2$) is estimated from Table 2 to be 0·45 for the transformed data. Thus forty-five three-leaf samples taken at random will give an estimate of population density with a standard error of about 25 per cent of the mean. This will enable densities differing by a factor of two or more to be distinguished. The accuracy of the estimate of mean density obtained from different numbers of three-leaf samples is indicated in Table 4.

TABLE 4

STANDARD ERRORS OF ESTIMATED MEAN POPULATIONS PER THREE LEAVES FOR DIFFERENT NUMBERS OF THREE-LEAF SAMPLES TAKEN WITHIN A FIELD

Number of Three-leaf Samples (One only from any given plant)	Standard Error of Mean Log (N + 1)	Factor for 5 per cent Limits of Mean Count
1	0·67	
2	0·47	
5	0·30	4·0
10	0·21	2·6
20	0·15	2·0
50	0·09	1·5
100	0·07	1·4
200	0·05	1·3

The third column of the table gives the order of proportional error which may be expected for samples of different sizes. Thus if the estimate of mean count per sample is 50, based on samples from 20 plants, the 5 per cent fiducial limits are approximately : $50 \times 2{\cdot}0 = 100$ aphids per sample, and $50 \div 2{\cdot}0 = 25$ aphids per sample.

It is not normally practicable to keep individual three-leaf samples separate for washing and counting in view of the great increase in time taken to handle

* The variance of the estimated population of a field (in terms of log (n+1) aphids per three-leaf sample), based on r samples taken from each of n plants at random, is

$$\frac{1}{n}\left\{\sigma_2^2 + \frac{\sigma_1^2}{r}\left(1 - \frac{r}{10}\right)\right\}$$

Using estimates of σ_1^2 and σ_2^2 from Table 2, and substituting r = 1 and r = 10 with nr constant, the result quoted is obtained.

(475) A***

them, compared with a bulked sample. Bulking involves some loss of information, and where this has to be done the sample size should be increased by 25–30 per cent to compensate for it. In critical work it must also be remembered that average densities calculated from mean log counts are biased (to the extent of about 10 per cent with the present data) relative to those estimated from bulked samples.

REGIONAL ESTIMATES OF APHID POPULATION

When an estimate of the average aphid population density is required for a province or the whole country, and the examination of plant material is a limiting factor, the most economical way to collect the information may be to visit a large number of fields and to sample each field much less intensively than would be required to obtain an accurate estimate of its population density. Some counts of live aphids on sprout plants in January 1948, provided by Empson, are used to illustrate this point. Ten plants were examined on each of eighty fields chosen more or less at random throughout England and Wales. The overall mean population for these fields was three aphids per plant. An analysis of variance has been carried out on the logarithms of the plant counts and is given below.

Analysis of Variance of Log (N + 1) Aphids per Plant (January, 1948)

Factor	d.f.	M.S.	Expected Value of Mean Square
Between fields	79	3·17	$10\,\sigma_2^2 + \sigma_1^2$
Within fields	720	0·29	σ_1^2

As might be expected, the analysis shows that there is far greater variation in overwintering aphid populations per plant between fields than within fields. Using values of the variance components between and within fields, estimated from this analysis (σ_2^2 and σ_1^2 respectively) in conjunction with the formula given by Yates (1949, section 8.17.g) estimates of the efficiency of alternative sampling schemes can be obtained. For example, if it takes three minutes to examine a plant and estimate the aphids present, and half an hour to get to a field, then charging travelling time as double, the most accurate estimate for given total cost would be obtained by examining about five plants per field. However, the efficiency does not vary rapidly with the number of plants per field sampled, and a much larger number of plants would evidently have to be examined if any use was to be made of the individual field estimates.

A similar calculation might be made for the very different conditions in summer, when heavy infestations are estimated in the manner described earlier in this paper.

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CONTROL OF CABBAGE ROOT FLY IN THE SEEDBED

by T. ROSBOROUGH*

Royal Agricultural College, Cirencester

Experiments on the control of Cabbage Root fly, *Erioischia brassicae* Bouché, were carried out in 1953 on six brassica seedbeds in the Cirencester area. Each insecticide referred to in the table below was applied as a band of dust approximately two inches wide along the plant row when the plants had reached the second to third rough leaf stage. Three to four weeks later, when the plants had grown to a size suitable for transplanting, a number were taken at random from each plot and examined ; those showing any sign of larval attack were recorded as damaged. No attempt was made to assess the degree of injury. In seedbed A, 180 plants were examined, and in seedbeds B, C, D, E and F, 120, 720, 300, 240 and 270 respectively. There were three replications of each treatment in the beds A, B, E and F, six in C, and two in D.

Dust Used	Percentage of Plants Damaged by Larvae					
	A	B	C	D	E	F
Calomel, 4 per cent	5·0	10·0	10·8	10·0	53·3	16·7
Toxaphene, 5 per cent	—	30·0	—	—	—	—
Toxaphene, 10 per cent	—	—	29·2	36·0	—	—
Aldrin, 1·5 per cent	11·7	—	21·7	22·0	40·0	—
Dieldrin, 1·5 per cent	—	6·7	10·8	4·0	30·0	8·9
Gamma-BHC, 0·26 per cent ..	—	—	26·7	28·0	—	—
Control, untreated	40·0	40·0	42·5	42·0	78·3	75·5
Significant difference (P = 0·05)	8·9	3·0	8·4	12·4	6·0	4·5

The results show that the dieldrin dust was more effective than any of the other materials tested. The aldrin dust gave a significant reduction in the number of plants damaged but, except on seedbed E, it was not as effective as the standard 4 per cent calomel treatment.

The 5 per cent toxaphene dust used in one experiment only (seedbed B) gave results inferior to those obtained with the dieldrin and calomel dusts. On seedbeds C and D a 10 per cent toxaphene dust was not so effective as the other materials. The dust containing 0·26 per cent gamma-BHC used on seedbeds C and D did not give as good protection as the dusts containing aldrin, dieldrin or calomel.

* Now at College of Technology, Belfast, N. Ireland.

EFFECT OF DOWNY MILDEW ON YIELD OF SUGAR BEET

by C. E. CORNFORD

Rothamsted Experimental Station
(Dunholme Field Station, near Lincoln)

Downy Mildew (*Peronospora schachtii* Fuckel) is probably the most destructive fungus disease of sugar beet in Great Britain, but there is little information on the extent to which it affects yield. A preliminary experiment made in Lincolnshire in 1943 showed that sugar beets infected in June and harvested in October yielded only half as much as healthy beets (Hull, 1950). Similar losses were reported in California by Leach (1945). This paper summarizes the results of three field experiments, carried out in 1947, 1948 and 1949 respectively, in which the weights of roots of healthy and infected sugar beets were compared.

On April 18, 1947, part of a field was drilled with sugar beet seed of the variety Kuhn E ; after gapping and singling, it was divided into six blocks of five plots, each plot measuring 15 feet by 14 feet 8 inches and having 112 plants for lifting. The treatments, which were arranged in the blocks in random order, consisted of inoculations applied once only to each plot, on the dates shown in Table 1. The inoculations were done by placing a few drops of conidial suspension on the tiny central leaves of each plant. To check the rate at which the inoculum evaporated, the inoculations were made during the hour before sunset. In addition, the inoculated plants were covered for one day with wet sacks. On October 17 the sugar beets were lifted, topped, washed and weighed, and samples of beets were tested for sugar content.

TABLE 1

DEVELOPMENT OF DOWNY MILDEW IN RELATION TO DATE OF INOCULATION, AND EFFECT ON YIELD

Date of Inoculation	Maximum Percentage of Plants developing Infection	Yield of Washed Beet *tons per acre*		Difference from Control *tons per acre*
1947 June 3	80	7·58	±0·337	−2·45*
June 30	29	9·35		−0·68*
July 24	11	9·76		−0·27
Control	15	10·03		
1948 June 9	51	8·90		
July 12	3	Not sampled		
August 10	1	Not sampled		
September 14 ..	1	Not sampled		
Control	2	8·55		
1949 June 21	29	5·12	±0·228	−0·79*
July 19	39	5·41		−0·50
August 16	15	6·30		+0·39
September 28 ..	0	6·15		+0·24
Control	10	5·91		

* Significant at 5 per cent probability level.

The inoculations made on June 3 and June 30, 1947, significantly decreased the yield of washed beet (Table 1). The earliest inoculation infected the greatest proportion of plants and caused the greatest loss. The disease also greatly decreased the yield of sugar per acre, calculated as the product of root yield and

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sugar percentage. The yields were 29·84, 37·25, 39·67 and 39·01 ± 1·568 cwt. per acre of sugar for the plots inoculated on June 3, June 30, July 24 and for the two control plots, respectively.

New Mexico College of Agriculture and Mechanic Arts

On March 31, 1948, part of a field was drilled with sugar beet seed of the variety Battle's E, and, after gapping and singling, was marked into plots similar to those used in 1947. The plots were arranged as a 5 × 5 Latin Square. The inoculations, made on the dates shown in Table 1, were not all successful, and only those on June 9 caused more infections than occurred on the control plots. Only plots of these two treatments were harvested on November 4, when the yields from the inoculated plots did not differ greatly from those of the control plots. Comparisons between the weights of individual beets showed, however, that Downy Mildew decreased the yield of washed roots by 30·8 per cent. The two middle rows of each of the five plots inoculated on June 9 contained 80 infected plants, and the mean weight of their roots was 0·527 ± 0·021 lb. These same rows contained 59 healthy beets and the mean weight of their roots was 0·762 ± 0·026 lb. The difference between these means was significant at the 5 per cent probability level. The sugar percentage of the diseased roots was 15·61 per cent, compared with 16·67 per cent in healthy plants.

On April 27, 1949, sugar beet seed of the variety Dobrovice was sown over an area measuring 69 × 112 feet, which was divided into plots arranged as a 5 × 5 Latin Square with randomized treatments, as in the 1948 experiment. Inoculations were made on the dates shown in Table 1, and the roots were harvested during the period November 9–21. The inoculations made on June 21 significantly decreased the yield of roots. This decrease, and the plot yields in general, were lower than in previous years, probably because the beet were sown late and Virus Yellows occurred early. The weights of individual plants of known history showed that Downy Mildew caused significant losses in plants which first showed symptoms on July 18 and August 8 (Table 2).

TABLE 2

EFFECT OF DOWNY MILDEW ON THE WEIGHTS OF INDIVIDUAL ROOTS IN 1949

Plants first Seen to be Infected on :	Number of Roots	Mean Weight of Roots *grammes*	Difference from Control *grammes*	Loss of Root Weight *per cent*
June 29	5	254·0	−29·6	−10
July 18	40	179·5	−104·1*	−37
August 8	33	204·6	−79·0*	−28
September 1 ..	45	273·6	−10·0	−3
September 30 ..	29	371·5	+87·9	+31

* Significant at 5 per cent probability level

To sum up, it may be said that in the course of these trials, early inoculation with Downy Mildew produced up to 80 per cent of infected plants and decreased the yield of plots by nearly 2½ tons per acre of washed roots, or 24·4 per cent of the yield of untreated plots. When the weights of roots from individual plants of known history were compared, losses up to 37 per cent were measured in plants that developed symptoms in July.

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NEW RECORDS OF LEGUME VIRUS DISEASES IN ENGLAND

by PATRICIA J. KLESSER*

Agricultural Research Council, Plant Virus Unit, Molteno Institute, Cambridge

A survey of the virus diseases of the Leguminosae occurring naturally in England was made during 1948–50. Common Bean Mosaic, Pea Mosaic, Pea Enation Mosaic, Soybean Mosaic, and a Tropaeolum Ring Spot (which also occurs on broad beans) had already been reported, but Bean Yellow Mosaic, Pea Stunt (Pisum Virus 6. Weiss), Alsike Clover Mosaic and White Clover Mosaic were found for the first time in England.

Bean yellow mosaic virus was found at Cambridge in French bean (*Phaseolus vulgaris*), broad bean (*Vicia faba*) and trefoil (*Medicago lupulina*). It is transmissible by *Aphis fabae* and *Myzus persicae*, but is not seedborne. The characteristic symptom on the bean is a marked reflexing of the middle leaflets at the pulvinus at right angles to the petiole (Plate II, 1). Leaves show a vivid chlorotic mosaic and are puckered and curled downwards (Plate II, 2). The host range includes the garden pea, alsike (*Trifolium hybridum*), crimson clover (*T. incarnatum*), and sweet clovers (*Melilotus alba* and *M. officinalis*) (Plate II, 3).

Pea stunt virus was found in trefoil near Cambridge. It is transmitted by *Macrosiphon pisi* and *Myzus persicae*, but not through the seed. In the pea there is a severe necrosis and collapse of the inoculated leaves, followed by a systemic necrosis of the leaf veins, petioles and stem, and complete collapse in 18–20 days (Plate II, 5). At lower temperatures there may be only a chlorotic spotting and mottle with extreme rosetting. Sweet pea, sweet clover (yellow and white), French bean (Plate II, 4), soybean, broad bean, alsike, crimson clover, and white clover (*T. repens*) are also susceptible.

Alsike clover mosaic virus was found at Cambridge in spotted medick (*Medicago arabica*). It is transmitted by *Myzus persicae* but is not seedborne. On the bean there may be small local necrotic spots surrounded by a chlorotic halo. The young leaves develop small chlorotic spots which enlarge and fuse to a mottle (Plate III, 1). The leaves are crinkled and the plant is stunted. The host range is wide and includes sweet pea, garden pea, trefoil (Plate III, 2), lucerne, soybean, broad bean, alsike, crimson clover (Plate III, 3), red clover (*T. pratense*), and sweet clovers.

White clover mosaic virus was found at Cambridge in lucerne (*Medicago sativa*). It is transmitted by *Aphis fabae* but not through the seed. On the French bean a local necrotic spotting is the only reaction (Plate III, 4). Broad bean (Plate III, 5) and pea show local necrosis, as well as a severe systemic effect of chlorotic markings, followed by a veinal and stem necrosis and ultimate collapse. The virus also induces symptoms on soybean, lucerne, crimson clover, and red clover.

* Now at Division of Plant Pathology, Department of Agriculture, Pretoria, Union of South Africa.

NAPOMYZA LATERALIS (FALL.)

A NEW PEST OF CALENDULAS

by H. G. MORGAN

National Agricultural Advisory Service, Starcross, Exeter

In Devon and Cornwall improved strains of the garden marigold, *Calendula officinalis*, are often grown for the winter cut-flower trade. Though the financial returns from them are not usually as good as from the choicer blooms such as violets and anemones, they are normally a trouble-free crop. In the winter of 1949–50, a number of reports were received in the Entomology Department at Starcross that flowers, apparently healthy when packed, were wilting on the way to market. The trouble proved to be due to the larvae of a fly boring in the capitulum, and when the flies emerged they were identified by Mr. J. E. Collin as *Napomyza lateralis* (Fall.).

A search of the literature did not reveal any previous reports of damage in Great Britain, although *N. lateralis* is a native insect, and it had in fact been bred a few years previously from larvae mining in the stems of garden sage at Newton Abbot. Abroad, it had been recorded from Belgium as a pest of Witloof chicory, where eggs laid before lifting develop into larvae which mine the chicons in the forcing house (van den Breul, *Bull. Inst. agron. Gembloux*, 1933, **2**, 17–44 ; 1937, **6**, 218–55 ; and 1939, **8**, 223–30). Insecticidal treatments had proved ineffective in controlling the pest, and the standard control measure developed at Gembloux was a hot-water treatment (2 hours at 105° F.) of the roots before forcing. In August 1950, it was reported by the N.A.A.S. entomologists to be common in *Calendula* in the Reading district. A case of damage on *Dimorphotheca* was seen in Cornwall in March 1950, and in the spring of 1953 it was recorded on cornflowers near Cambridge (E. B. Brown, *in lit.*). Attempts to infest field and Witloof chicory at Starcross were unsuccessful.

LIFE HISTORY

On *Calendula*, the eggs are laid on the upper surface of the leaves, usually near the tips. The female fly bores a hole with her ovipositor and then moves backwards to feed on the sap. After this she sometimes moves forward and deposits an egg, but many of the punctures are feeding holes only. In appearance they resemble very closely those of Chrysanthemum Leaf Miner (*Phytomyza atricornis*) on chrysanthemums. When the egg hatches, the larva bores a superficial mine and wanders through it over the surface of the leaf until it encounters a vein. It then moves quickly down the vein and midrib, and down the petiole into the stem (Plate I, 4). On reaching the main stem, the larva sometimes remains near the node and pupates in the mine there. Normally, however, it moves up the stem until it reaches the capitulum, where it continues to mine until it is ready for pupation. The length of the life-cycle varies according to temperature. In summer it normally takes about 7 weeks from oviposition to emergence, but in winter it may take 10–12 weeks. The Belgian workers found generation times ranging from 51 to 70 days in spring and summer, and state that the fly hibernates in the larval stage, fully-grown larvae present in the autumn pupating in March and April and emerging in May (van den Breul, 1936, 1939). In Devon and Cornwall, hibernation does not seem to occur, and flies may emerge in January and February from eggs which were laid in November or December. In Belgium, it is possible to distinguish three generations in the year, even though overlapping occurs, but in the South-West, the fly is practically

continuously brooded, and apparent separate generations in any particular crop are largely artefacts due to the stage of growth at which the crop was attacked, or to a sudden onset of warm weather.

Three types of damage occur which may be of economic importance. Attack in the seedling stage may cause death of the primary growing point, giving rise to a " many-necked " type of plant (Plate I, 1). This in itself may not be a disadvantage unless the secondary crowns are themselves attacked and killed out, so that the entire plant is crippled. Attack at a later stage of growth may weaken the stems, particularly at the nodes, which leads to breakdown of the plants under the stress of wind, mechanical cultivation or picking. Still later attack will cause damage to the flowers, either killing the bud before it opens (Plate I, 2) or causing it to wilt after picking.

WEED HOSTS

The fly can also breed on a wide range of weed hosts. The Belgian workers mention *Matricaria*, *Senecio*, *Centaurea*, *Urtica* and *Anthriscus* (van den Breul, 1939), but with us groundsel (Plate I, 3) is certainly the most important weed host, and probably the only one of commercial importance. It is probable that thorough weed control and destruction of old *Calendula* plants before the new crop is sown would be of some value in controlling the pest, but if there are nearby sources of infection, the absence of groundsel, which seem to be more attractive than *Calendulas*, might concentrate the attack on the crop.

PARASITES

A number of parasites of *Napomyza lateralis* have been recorded, including the Braconids *Rhizarcha pubescens* (Curtis) and *Dacnusa leptogaster* Hal., the Pteromalids *Sphegigaster aculeatus* (Walker) and *Stenomalus muscarum* (L.) and the Chalcid *Halticoptera fuscicornis* (Walker). The last-mentioned is already very common in Britain, being the common parasite of *Oscinella frit*, so that the chances of biological control seem to be remote.

CONTROL

Attempts to work out control measures have not so far been successful, partly because the fly was very scarce in 1950–51 and 1951–52. Treatment of the seed with schradan before sowing gave no apparent control, and there was no effect on the rate or percentage of germination. Monthly sprayings with schradan and fortnightly sprayings with BHC and parathion were tried from August to November 1951. All three treatments reduced the infestation in groundsel plants growing in the rows to about 30 per cent, as compared with 50 per cent in unsprayed controls. There was not sufficient damage to the crop to make valid counts possible.

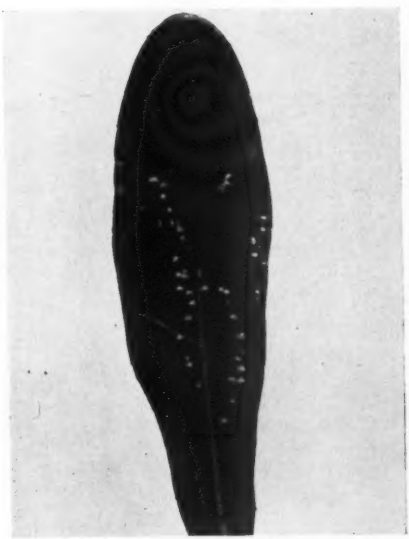
Calendulas are grown as a cheap crop, and the growing period, from July to March, is long, with the plants open to attack all the time. Full protection by spraying, even if it were possible in practice, would be prohibitively expensive, and perhaps the best that could be done would be to attempt to control the November egg-laying, and so protect the flowers at the time when prices are likely to be highest.

Thanks are due to Mr. H. C. Woodville for the photographs.

1. "Many-necked" plant of *Calendula* showing growth of secondary crowns due to killing of primary shoot.

2. *Calendula* shoot showing killing of terminal bud and oviposition punctures and mines on leaves.

3. Damage to groundsel, the principal weed host, showing destruction of the primary stem and resultant branching.



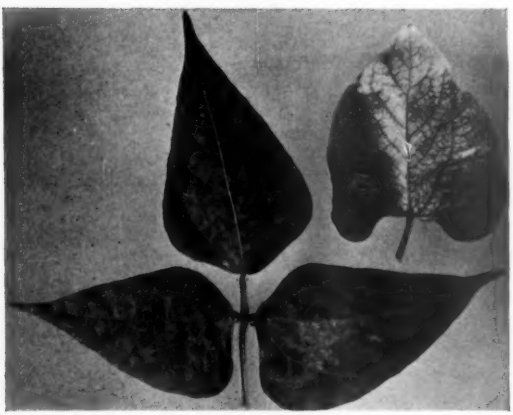
4. *Calendula* leaf showing feeding marks and superficial mine leading from oviposition puncture to mid rib.

PLATE I

BEAN YELLOW MOSAIC

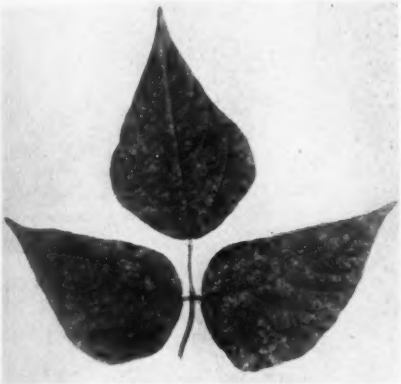
1. On French bean, showing reflexing of middle leaflets at the pulvinus.
2. *Above* : On French bean, showing leaf puckering.
3. *Below* : On sweet clover.

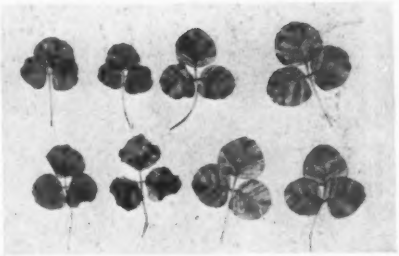
PEA STUNT

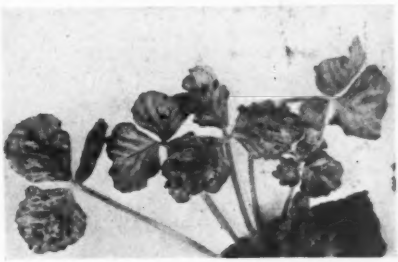


4. Pea Stunt on French bean, showing chlorotic spotting and mottle.
5. *Right* : On garden pea, showing severe necrosis and collapse of inoculated leaves.

ALSIKE CLOVER MOSAIC







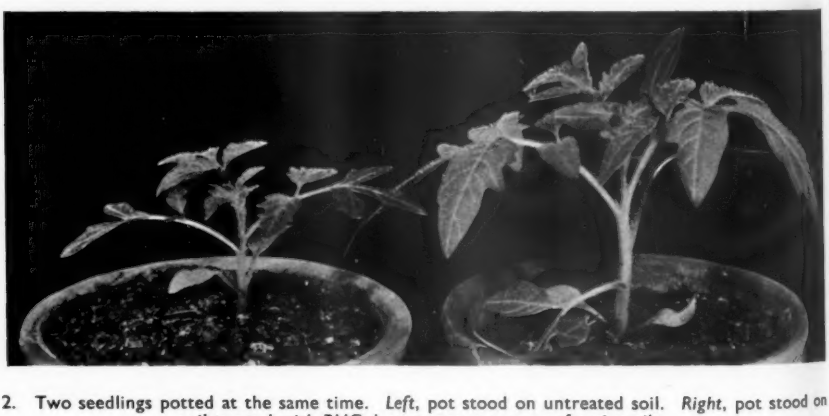
1. On French bean, showing small chlorotic spots which enlarge and fuse to a mottle.
2. *Right, above :* On trefoil.
3. ,, *below :* On crimson clover.

WHITE CLOVER MOSAIC

4. White Clover Mosaic on French bean, showing local necrotic spotting.
5. *Right :* On broad bean, showing stem necrosis, local necrotic spotting and collapse of leaves.

PLATE III

1. Injury just below soil level in young seedling, and severe pitting and chewing off of roots in seedling at later stage of growth.



2. Two seedlings potted at the same time. *Left*, pot stood on untreated soil. *Right*, pot stood on soil treated with BHC dust to prevent entry of springtails.

SPRINGTAIL DAMAGE TO TOMATOES

by E. B. BROWN

National Agricultural Advisory Service, Cambridge

In February 1953, a nurseryman at Waltham, Essex, found small white insects damaging his tomato seedlings growing in 3-inch pots under glass. On investigation these proved to be springtails, and in a random collection three species were present in the following proportions: *Onychiurus stachianus* Bagnall 1939 (= *O. fimetarius* (Linn.) partim) 355 specimens; *Onychiurus nemoratus* Gisin 1952 (= *O. armatus* (Tullberg) partim) 191 specimens; and *Anurida granaria* (Nicolet), 38 specimens.

Contrary to normal practice in the Lea Valley, the pots had been placed directly on the soil surface of the propagating house. A large proportion of the 50,000 plants in the house was seriously retarded and many plants were killed. The plants were going off after being in the house for 10–14 days and it was evident that the insects were entering the pots through the holes in the bottoms.

Growing conditions had been very poor for the previous few weeks as there had been little sun. Some plants near the hot pipes were growing better, but even here many were affected. Watering had been very liberal and it was thought that this may have been a factor in attracting the insects to the pots. Organic manures had not been dug into the soil, as was usually done before the pots were stood in the house, and this may have caused the springtails to look elsewhere for food. The house had been steam sterilized during the winter using the " harrow " method.

The plants had made very little growth and the main damage was to the stem below and just above soil level. Many seedlings were toppling over as a result of the hole about the size of a pin head made in the stem near soil level (Plate IV, 1). Later, as the surviving plants attempted to throw new roots, these were immediately chewed off, and many of the stems were severely pitted. An examination of the root systems of plants that had managed to recover showed that numerous holes had also been made in the roots. Some of the insects were found inside the holes made in the stems.

A water flotation method was found to be very effective for the recovery of springtails from soil samples, as the insects are waxy and do not jump. In cores 4 inches in diameter and 6 inches deep taken from places where the pots had been standing, a population of springtails equivalent to over 33 million per acre was found, and no doubt many had been removed in the pots. The insects were recovered from individual pots by washing the pot contents through a Fenwick eelworm flotation apparatus (Fenwick, *J. Helminth.*, 1940, **18**, 155–72), and filtering the float through black filter paper. The number of springtails per pot averaged 98 (46 pots examined) with a maximum of 309 and a minimum of 30. The potting loam had been stored in a heap in the glasshouse and it also contained a few springtails, but not in sufficient numbers to cause damage.

CONTROL MEASURES

Various treatments of the soil surface in the house were tried in an effort to prevent the insects from entering pots containing newly-potted seedlings. Both 4 per cent nicotine dust and 0·05 per cent DDT emulsion (half a gallon per square yard) were ineffective, but BHC wireworm dust, applied at half an ounce per square yard, gave good results and the seedlings grew normally (Plate IV, 2).

Insecticides were also applied to pots containing attacked plants. Waterings of about 2 fluid ounces per pot with 0·05 per cent nicotine and 0·0125 per cent parathion gave no reduction in the number of springtails in the pots. Gamma-BHC emulsion, however, at a concentration of 0·00625 per cent, applied at the same rate round the edges of the pots with care not to wet the plants, affected the insects almost immediately. The plants in the pots which received this treatment began at once to push out new roots and they grew away normally.

Sheets of cardboard put down between the pots and the soil delayed the entry of the insects sufficiently to enable newly-potted plants to grow away, but very large numbers congregated underneath the cardboard and eventually found their way round the edges into the pots. Pots placed on a temporary staging proved inaccessible to the insects and the plants in them also quickly became established.

Severe damage to tomato seedlings by springtails has not previously been recorded. One of the species (*Onychiurus armatus*) has been recorded damaging the foliage of lettuce under glass by Speyer (*Rep. exp. Res. Sta., Cheshunt*, 1934, 74). Here, leaves touching the soil were at first pitted and then partially skeletonized. I saw similar damage on the cotyledons of cucumber plants under glass in January 1951, where springtails were present in large numbers.

Thanks are due to Mr. J. E. E. Jenkins for drawing attention to the problem, to Dr. H. E. Goto of the Imperial College of Science and Technology, for the identification of the springtails, and to Mr. W. E. Dant for the photographs.

FURTHER OBSERVATIONS ON DELAYED SPORULATION OF *PHYTOPHTHORA INFESTANS* ON INFECTED POTATO SHOOTS

by MARGARET A. KEAY

Agricultural Research Council,
Potato Genetics Station, Cambridge

In the previous paper (*Plant Pathology*, 1953, **2**, 68–70) it was reported that *Phytophthora infestans* (Mont.) de Bary, strain B^2 was recovered at the end of the growing season from the stems of plants of the potato variety Canso, which were grown outside from naturally-infected tubers. It seemed from the evidence that this stem infection developed from that in the tubers. Nevertheless, infection might have arisen from some other source and, if it had, it would be expected that strains B^1 or B^2 would bring it about, as the variety Canso is resistant to strains A and C. It was decided, therefore, to repeat the experiment in a modified form.

Delayed Sporulation of Phytophthora Infestans

In February 1953, six tuber samples of King Edward were each inoculated with isolates belonging to strains A, B^1 (2 isolates used), B^2 and C (30 tubers in all). The strains were those as defined by Black (*Proc. roy. Soc. Edin.*, B, 1952, **65**, 36–51). The tubers were kept in a cold room until March 27, when three tubers inoculated with each strain and five healthy tubers were planted in pots of sterilized potting compost and put on a glasshouse bench. All of the healthy tubers and eight of the fifteen infected ones produced plants. Basal necrosis developed on three plants from infected tubers and *P. infestans* was recovered from one of them. The plant from which the fungus was recovered was one that had been inoculated with strain A ; it first showed basal necrosis on two shoots on May 8. By June 9, seventy-four days after planting, necrosis extended upwards on four shoots for 7, 14, 14 and 20 cm. respectively. When the plant was put in a damp atmosphere, the fungus spored on two of the stems to a height of 16 and 24 cm. respectively. The fungus recovered proved to be strain A.

Fifteen of the inoculated tubers were stored from March 27 to April 15 at +8° C., when they were moved to room temperature. On April 21, the inoculated tubers, together with five healthy ones, were planted in pots of sterilized potting compost. By May 13 all the healthy tubers and seven of the blighted ones had produced plants which were put outside in a permanently open cold frame. Observations were made twice weekly. Ten plants remained blight-free throughout the summer. On June 5 necrosis was visible to a height of 7 cm. on a stem developed from a tuber inoculated with strain B^1. During the next twelve days the necrosis extended only another 1 cm. The plant was put in a damp atmosphere, where the *P. infestans* which developed on the necrotic tissues was rapidly over-run by moulds and the strain was not identified.

On June 24, sixty-four days after planting, *P. infestans* was found to be sporing on the basal 4 cm. of a stem from a tuber infected by one of the B^1 isolates ; three days later sporulation was abundant to a height of 7 cm. The infected stem was removed and the strain of the fungus was identified as B^1. The other stems on this plant remained free from blight.

In this experiment there were twenty-five plants—fifteen from inoculated tubers, and ten from healthy ones. The only disease symptoms seen were on the stems of five plants grown from inoculated tubers. From the stems of two of these plants *P. infestans* was recovered and the strain found to be the same as that with which the tubers had been inoculated. It seems virtually impossible that this could have happened unless the infection came from the tubers.

My thanks are due to Miss G. B. Browne for her technical assistance.

TRIALS OF SUBSTITUTES FOR SULPHURIC ACID FOR POTATO HAULM KILLING, 1952 AND 1953

Contribution from the Conferences of Crop Husbandry Officers and Plant Pathologists, National Agricultural Advisory Service, compiled by E. C. Large of the Plant Pathology Laboratory, Harpenden

The trials started in 1951 (*Plant Pathology*, **1**, 2–9, 56–9) were continued in 1952 and 1953, to test the efficacy of the treatments under differing seasonal conditions. Mechanical haulm destruction was included in both years ; low-volume application of sodium arsenite was tested in 1952 ; and in 1953, at the suggestion of Dr. A. R. Wilson, of the Agricultural Research Council, Potato Storage Investigation Unit, Sutton Bonington, a by-product of tar distillation containing ammonium thiocyanate as its active constituent was brought into the trials. The present contribution summarizes the results in 1952 and 1953 and concludes the account of the work. The design of the trials and methods used were the same as in 1951, except where otherwise stated.

TRIALS IN 1952

In trials at 11 centres in 1952, sulphuric acid (BOV) at about 20 gallons per acre, either undiluted in low-volume application, or in 80 gallons of water in high-volume application, was compared with the tar oil fraction (TOF 54) at 25 gallons per acre, and sodium arsenite (98 per cent As_2O_3 wt./vol.) at 1 gallon in 24 gallons of water per acre in low-volume application or 1 gallon in 99 gallons of water in high-volume application.

The dates of spraying and mechanical destruction in relation to the course of blight on the haulm at each centre are shown in Fig. 1, and the critical comparative assessments of stem and leaf kill by the chemical treatments are given in Table 1. The observations on the state of the debris in the furrows after mechanical treatment cannot conveniently be presented in tabular form, but the centres at which the several machines were used are shown in Table 2, which gives the percentage of blight in tubers following all treatments. As in 1951, five sample runs of five plants, located at random in each plot, were lifted by hand on the dates given in the table, and the number of blighted and healthy tubers in each sample was counted. The tubers were then stored in sacks for six weeks, when a further count was made.

The rotary hoe machine referred to in the tables for both 1952 and 1953 was the Howard Potato Haulm Pulverizer, or " Rotavator " (Rotary Hoes Ltd., East Horndon, Essex). The rubber flail was the " Rotoflail " (Pest Control Ltd., Cambridge) ; the hammer pulverizer was the Leverton machine (H. Leverton & Co. Ltd., Spalding, Lincs) ; and the horizontal cutter was the Bettinson machine (P. B. Bettinson & Co. Ltd., Holbeach, Lincs). The construction and mode of action of the machines were as described in the account of the trials held in 1951.

In general, it was found in 1952 that the cut green debris in the furrows was merely wilted after five days, and any blight on the foliage at the time of cutting was still sporing on the moister underparts. After the rubber flail and hammer pulverizer treatments, the leaves tended to dry up more quickly than they did after rotary hoe cutting, owing to the greater disintegration, but longer stems were left standing in the drills. By 14 days after mechanical destruction most of the debris was dead, whichever machine was used, and no blight was found on the debris after that time.

Potato Haulm Killing Trials

Table 1 .

Percentage Kill of Leaves and Stems at 5 and 14 Days after Application, 1952

"90 : 50" represents a 90 per cent kill of leaves and 50 per cent kill of stems. Upper figures give assessments at 5 days ; lower figures at 14 days.

Centre	*Variety and date of treatment*	*Sulphuric acid*	*TOF* 54	*Sodium arsenite (high vol.)*	*Sodium arsenite (low vol.)*	*Untreated control*
Cumberland ..	Redskin	98 : 98	85 : 75	98 : 95	80 : 70	50 : 10
	Sept. 4	100 : 100	100 : 90	100 : 100	95 : 90	75 : 25
Yorkshire ..	Majestic	100 : 98	98 : 90	90 : 50	80 : 50	5 : 1
	Sept. 15	100 : 100	100 : 99	100 : 98	100 : 98	60 : 40
Lincoln ..	King Edward	80 : 20	95 : 5	95 : 20	95 : 10	5 : 5
	Aug. 28	98 : 80	98 : 75	100 : 95	100 : 92	10 : 5
Cheshire ..	Arran Peak	100 : 75	90 : 40	95 : 10	90 : 50	5 : 1
	Sept. 9	100 : 87	90 : 80	100 : 90	100 : 90	40 : 5
Isle of Ely ..	King Edward	100 : 50	97 : 40	95 : 30	90 : 30	22 : 4
	Aug. 19	100 : 100	100 : 100	100 : 98	100 : 98	100 : 70
Worcester ..	Arran Banner	95 : 75	85 : 40	100 : 15	—	15 : 0
	Sept. 5	100 : 80	100 : 50	100 : 85	—	15 : 0
Worcester ..	King Edward	95 : 70	85 : 40	100 : 25	—	25 : 20
	Sept. 5	100 : 95	100 : 50	100 : 95	—	25 : 20
Monmouth ..	Majestic	100 : 95	—	100 : 80	100 : 90	50 : 10
	Sept. 1	100 : 100	—	100 : 100	100 : 97	90 : 20
Wiltshire ..	Majestic	100 : 90	98 : 95	95 : 85	97 : 90	10 : 0
	Sept. 17	100 : 100	100 : 99	100 : 97	100 : 98	30 : 10
Kent	Majestic	90 : 60	65 : 45	85 : 50	—	7 : 0
	Sept. 23	100 : 70	95 : 50	99 : 60	—	10 : 0
Hampshire ..	Majestic	100 : 85	95 : 60	98 : 60	—	75 : 55
	Sept. 15	100 : 98	100 : 90	100 : 90	—	95 : 70
Devon.. ..	Majestic	95 : 50	75 : 25	90 : 25	95 : 50	30 : 0
	Sept. 19	100 : 100	95 : 75	100 : 100	100 : 100	50 : 25

There was some variation in the order for effectiveness of the several treatments from centre to centre, but in general it was :

Sulphuric acid, high or low volume	1
Sodium arsenite, high volume	2
Tar oil fraction, low volume	
Sodium arsenite, low volume	

These results confirmed those obtained in 1951, and gave the additional indication that sodium arsenite may be equally effective at high or low volume.

Blight in the Tubers, 1952

In 1952, blight in the tubers was nil or negligible, with or without haulm destruction, at all the centres in the eastern half of the country. The blight attack on the haulm was late and an unusually cold September checked its progress, with the result that most of the haulm yellowed off or died down from causes other than blight, as indicated by the broken lines in Fig. 1. In several

of the trials, however, as at the Lincoln, Kent, Wiltshire and Devon centres, late protective spraying may have played a useful part in keeping even traces of blight off the haulm until September and thereby reducing opportunities for infection of the tubers in the soil.

There was a substantial amount of blight in the tubers from the untreated control plots at four of the centres on the western side of the country. At the Cumberland centre, haulm destruction, when there was 20 per cent of blight on the haulm, did not reduce the amount of blight in the tubers, thus indicating the occurrence of infection in the soil before the date of destruction. At the Cheshire centre, haulm destruction with acid, when there was about 25 per cent of blight on the haulm, reduced the blighted tubers to about ½ per cent (after storage), against 4½ per cent in the control. It will be noted that the control haulm was still partly green and blighted at lifting.

TABLE 2

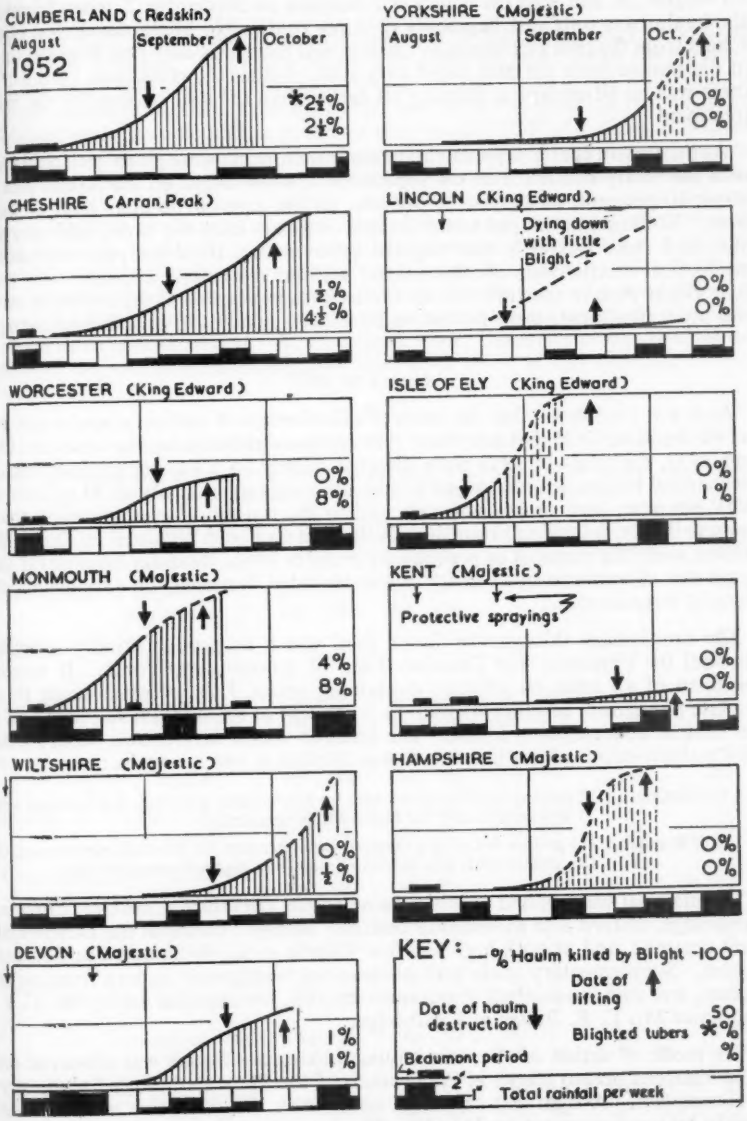
PERCENTAGE OF BLIGHTED TUBERS IN TRIALS AT 11 CENTRES, 1952

Upper figures : at lifting. Lower figures : after storage.

Centre	Cumb.	Yorks	Lincs	Ches.	Ely	Worcs	Mon.	Wilts	Kent	Hants	Devon
Variety	Rdskn.	Maj.	K.E.	Peak	K.E.	K.E.	Maj.	Maj.	Maj.	Maj.	Maj.
Treated	4.ix	15.ix	28.viii	9.ix	19.viii	5.ix	2.ix	17.ix	23.ix	15.ix	19.ix
Lifted	26.ix	14.x	17.ix	3.x	17.ix	16.ix	15.ix	14.x	6.x	29.ix	3.x
Soil cover ..	Poor	Aver.	Poor	Aver.	Good	Good	Aver.	Aver.	Aver.	Aver.	Good
Soil type* ..	M.L.	M.L.	Fen	Peat	Fen	Sand	H.L.	L.L.	H.L.	M.L.	M.L.
Sulphuric acid ..	1·8	0·0	0·0	0·6	0·0	0·0	2·2	0·0	0·0	0·0	0·0
	4·2	0·0	0·0	0·6	0·0	0·0	3·9	0·0	0·0	0·0	1·5
TOF 54	0·5	0·0	0·0	2·2	0·0	0·0	—	0·0	0·3	0·0	0·8
	0·5	0·0	0·0	3·0	0·0	0·0	—	0·0	1·9	0·5	1·6
Sodium arsenite..	1·8	0·0	0·0	1·3	0·0	0·4	9·5	0·0	0·0	0·0	0·0
(High vol.)	2·6	0·0	0·0	1·3	0·7	2·1	11·3	0·0	0·0	0·5	0·8
Sodium arsenite..	0·0	0·4	0·0	0·5	0·3	—	2·9	0·0	—	—	—
(Low vol.)	1·1	0·8	0·0	3·0	0·8	—	4·6	0·0	—	—	—
Rotary hoe ..	—	0·0	—	1·3	0·3	1·0	—	0·0	0·0	—	0·0
	—	0·5	—	1·3	1·3	2·0	—	1·3	0·0	—	0·0
Rubber flail ..	—	—	—	—	—	—	—	0·0	0·4	—	1·4
	—	—	—	—	—	—	—	0·7	1·5	—	2·1
Hammer ..	—	—	0·0	—	—	—	—	—	—	—	—
pulverizer	—	—	0·0	—	—	—	—	—	—	—	—
Control	2·0	0·6	0·3	3·1	0·0	1·0	7·0	0·0	0·0	0·0	0·7
(untreated)	2·5	0·6	0·6	4·5	1·2	8·3	8·1	0·5	0·0	0·0	0·7

* M.L. = medium loam ; H.L. = heavy loam ; L.L. = light loam.

On the King Edward at Worcester, the sample lifting was done when the control haulm was definitely blighted and green. About 8 per cent of blight developed after storage in the tubers from the control plots—indicating infection at lifting, as would be expected. Haulm destruction only 11 days before lifting appears to have prevented this infection when the most rapid method of destruction (acid) was employed, while the other treatments reduced it considerably. On the Majestic at the Monmouth centre, haulm destruction was not done until there was about 50 per cent blight on the haulm. There was therefore considerable opportunity for infection of the tubers in the soil before haulm destruction, but as the haulm was not all dead in the control plots at lifting, treatment with acid about halved the amount of blight in the tubers.



★Upper figures : haulm destroyed with sulphuric acid.
Lower figures : untreated control plots.

Fig. 1. Progress of blight on haulm, dates of haulm destruction and lifting, and rainfall, in relation to blight in tubers at each centre, 1952.

At the Wiltshire centre supplementary early treatments were tried, with acid on August 28, and with the rotary hoe machine on September 2, when blight on the haulm was only just beginning (0·1 per cent). No blight developed in the tubers from the plot mechanically treated, and there was only one blighted tuber in the sample from the plot killed with acid. Under the conditions of this trial there was no advantage in burning off earlier than the date chosen for the main treatment.

At the Devon centre supplementary early treatments were given with acid, and with the rotary hoe machine on September 4, when blight on the haulm was at about 10 per cent, as against 30 per cent on the date of the main trial 15 days later. No blight developed in the sample of tubers from the early, acid-sprayed plot, and there was only one blighted tuber in that from the plot with early, mechanical destruction. At this centre, with good earthing up, there was very little blight even in the tubers from the unsprayed control plots, and both early and main treatments were proved to have been unnecessary for blight control.

TRIALS IN 1953

As it was considered that the order of effectiveness of sodium arsenite and the tar oil fraction (TOF 54) had been sufficiently established by the trials in 1951 and 1952, the trials in 1953 were directed mainly to a further comparison of mechanical haulm destruction with acid spraying (again at about 20 gallons of BOV per acre, high or low volume), and to the testing of an ammonium thiocyanate liquor, following promising results that had been obtained by Dr. A. R. Wilson with this material in preliminary trials in 1952. Sodium arsenite (at the same rate of application as in 1952) was included, however, on supplementary plots at three centres.

The ammonium thiocyanate liquor used was a by-product kindly supplied for trial by Yorkshire Tar Distillers Ltd., of Knottingley, Yorks. It was in the form of an aqueous solution containing about 3 lb. of ammonium thiocyanate per gallon, together with up to 2 per cent of ammonium sulphate and 1 per cent of ammonium chloride. The solution was a dark-brown watery fluid with a slight odour of gas liquor. It was applied at two strengths :

Full Strength : 25 gallons (undiluted) per acre for low-volume spraying, or 25 gallons with 75 gallons of water for high-volume spraying.

Half Strength : 12½ gallons with 12½ gallons of water per acre for low-volume spraying, or 12½ gallons with 87½ gallons of water for high-volume spraying.

The material was applied at low volume at the Yorkshire, Cheshire, Lincoln, Cambridge, Oxford and Monmouth centres ; at high volume at the Devon and Kent centres ; and at both high and low volume at the Wilts and Cumberland centres. Supplementary trials with ammonium thiocyanate liquors from other sources, and with ammonium thiocyanate crystals, were carried out by Mr. C. V. Dadd and Mr. E. R. Bullen at Cambridge.

The mode of action of the ammonium thiocyanate liquor was observed on some vigorous potato plants in the grounds of the Plant Pathology Laboratory at Harpenden. A light but thorough cover with the undiluted material was applied by hand atomizer on June 18. The leaves were hanging limp, dark and with a soaked appearance by the evening of application. There was considerable rain during the night following, but by noon on June 20 all the leaves were completely bleached and hanging collapsed and limp, but not yet shrivelled ; the upper halves of the stems were bleached and doubled over. On June 22, after

four days, there was complete kill and withering of all the leaves and most of the stems.

In the trials at the centres, the performance of the ammonium thiocyanate liquor was variable. At centres where there was no rain during the spraying, and no heavy rain shortly afterwards, the kill of leaves and stems within 5 days, though nowhere equal to that with acid, was about as good as that generally obtained with sodium arsenite or the tar oil fraction (TOF 54). Some collaborators, such as those at the Kent centre, were not impressed with the performance of the material ; others, as those at Oxford, found it very effective and noted that it was clean and pleasant in use. At the Lincoln centre, the material hardly had a fair trial as the spraying was done during a shower, while that with the acid was done in the dry. At Cambridge, where there was continuous rain for twelve hours starting in the evening after the spraying, the kill of the stems was patchy, slow and inadequate, and the material was considered a poor substitute for acid. Other forms of the material tried at this centre under the same conditions gave similar results. At all centres where the material was tried at half strength the results were found to be inferior to those at full strength.

TABLE 3

PERCENTAGE KILL OF LEAVES AND STEMS AT 5 AND 14 DAYS AFTER APPLICATION, 1953

"90 : 50" represents a 90 per cent kill of leaves and 50 per cent kill of stems. Upper figures give assessments at 5 days ; lower figures at 14 days.

Centre	*Variety and date of destruction*	*Sulphuric acid*	*Thiocyanate (full strength)*	*Thiocyanate (half strength)*	*Sodium arsenite*	*Untreated control*
Cumberland ..	Majestic	100 : 40	100 : 10	—	—	50 : 0
	Aug. 21	100 : 100	100 : 100	—	—	95 : 0
Durham ..	Arran Peak	—	—	—	100 : 75	80 : 30
	Sept. 21	—	—	—	100 : 100	95 : 90
Yorkshire ..	Majestic	100 : 95	95 : 80	95 : 75	—	75 : 25
	Sept. 23	100 : 100	100 : 100	100 : 100	—	100 : 95
Cheshire ..	Arran Peak	100 : 100	100 : 75	90 : 50	—	85 : 25
	Sept. 9	100 : 100	100 : 100	100 : 100	—	100 : 100
Lincoln ..	Gladstone	100 : 90	98 : 60	90 : 30	—	50 : 5
	Aug. 21	100 : 99	100 : 95	100 : 92	—	60 : 20
Cambridge ..	King Edward	100 : 90	95 : 10	—	—	75 : 10
	Aug. 19	100 : 98	100 : 85	—	—	90 : 60
Kent	Majestic	100 : 95	95 : 10	75 : 5	—	10 : 0
	Aug. 26	100 : 100	100 : 95	95 : 50	—	30 : 0
Oxford ..	Majestic (Scot)	90 : 30	75 : 20	55 : 10	50 : 30	4 : 0
	Sept. 12	99 : 90	99 : 95	99 : 85	100 : 95	10 : 4
	Majestic (O.G.)	90 : 30	65 : 10	40 : 5	30 : 10	4 : 0
	Sept. 12	99 : 90	99 : 95	90 : 75	70 : 55	6 : 0
Devon.. ..	Arran Banner	—	100 : 25	95 : 20	100 : 25	30 : 10
	Aug. 28	—	100 : 90	80 : 90	100 : 100	50 : 20
Wiltshire ..	Majestic	100 : 100	100 : 80	—	—	60 : 10
	Sept. 5–7	100 : 100	100 : 97	—	—	75 : 20
Monmouth ..	Majestic	100 : 60	99 : 30	95 : 8	—	50 : 10
	Aug. 25	100 : 100	100 : 50	100 : 70	—	75 : 20

RELATIVE EFFICIENCY OF THE TREATMENTS, 1953

As Table 3 shows, there was considerable variation from centre to centre in the order of merit of the materials as regards quickness of kill of stems and leaves, but over the trials as a whole the order was as follows :

Sulphuric acid, high or low volume	1
Sodium arsenite	2
Ammonium thiocyanate at full strength	
Ammonium thiocyanate at half strength	3

The action of the three types of mechanical haulm cutters or pulverizers, included in the trials as indicated in Table 4, was as in previous years. Except at the Kent centre, where the haulm in some of the rows had been crushed down by passage of the tractor in protective spraying, the rotary hoe machine gave an efficient cut and left very little " stubble ". The rotary flail left greater lengths of stem standing, but these were generally severely bruised and died down fairly quickly ; the horizontal cutter, when properly adjusted, cut the upright stems very close to the tops of the drills but inevitably missed some of the prostrate side haulms.

At some centres mechanical haulm destruction was considered rather slow, as compared with acid spraying, and occasionally there was some dragging of the stems and disturbance of the tubers where the drills were uneven. Apart from this, the only real drawback to mechanical destruction (often put equal or nearly equal to acid in point of general effectiveness) was that it tended to leave low-growing weeds (notably chickweed) untouched, whereas acid destroyed them.

There was often a little blight sporing on the debris in the furrows after 5 days, but even in so wet a season as 1953, the cut haulm was dead within about 14 days of cutting. Where a long " stubble " or uncut stems were left, blight continued to spore on them, as on the controls.

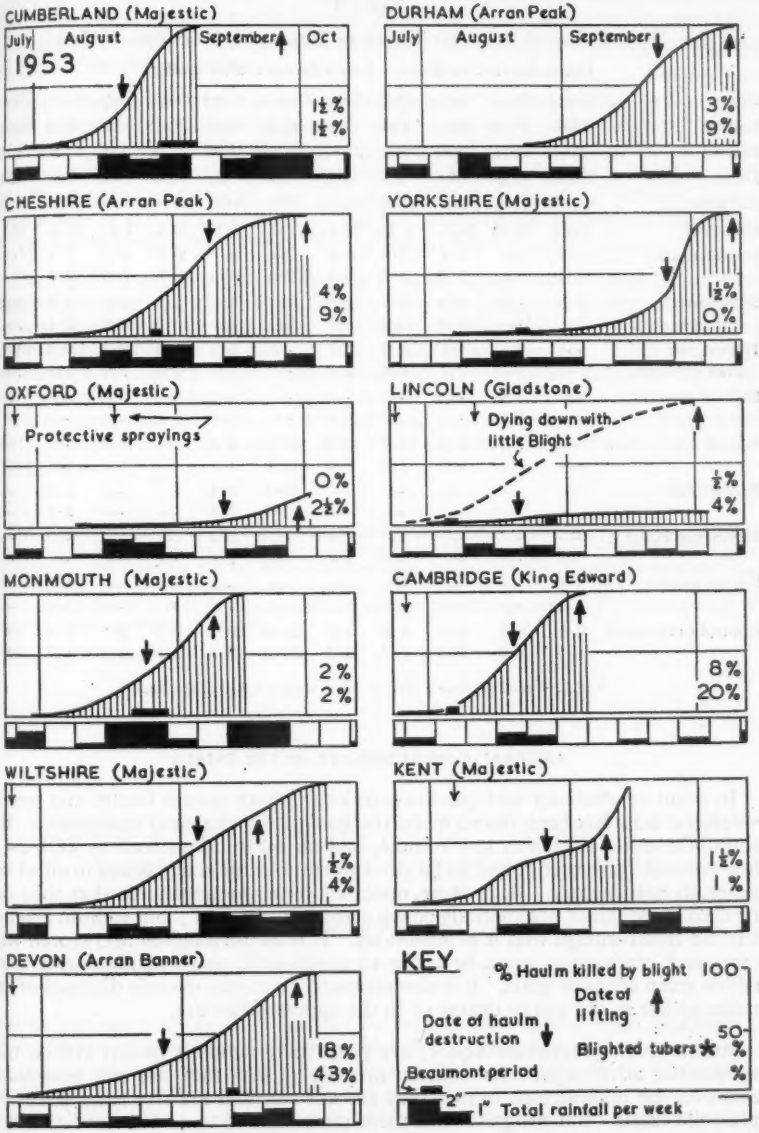
BLIGHT IN THE TUBERS, 1953

There was an earlier and more severe blight epidemic in 1953 than in the two previous years of these trials. The curves showing the progress of blight on the haulm of the control plots at all centres are plotted in Fig. 2, and the percentage of blighted tubers with each treatment at each centre are given in Table 4.

At the Cumberland, Monmouth, Yorkshire and Kent centres the percentage of blighted tubers even in the control plots was small, and haulm destruction made little or no difference. At the other centres the percentage of blighted tubers was, in general, about halved as a result of haulm destruction. The quicker kill with acid was reflected at most centres, but not at all, in rather lower figures for blight in tubers than those for the other chemical treatments.

In this year, when blight conditions generally were such as to provide a fairly severe trial, mechanical destruction at all but one centre resulted in no more, and often rather *less*, blight in the tubers than where destruction was done by acid or other chemical treatment. The exception was at the Cambridge centre, where the greater amount of blight with mechanical destruction probably reflected inequality of soil cover between the plots rather than any intrinsic difference of effect.

Potato Haulm Killing Trials



★Upper figures : haulm destroyed with sulphuric acid (or substitute).
Lower figures : untreated control plots.

Fig. 2. Progress of blight on haulm, dates of haulm destruction and lifting, and rainfall, in relation to blight in tubers at each centre, 1953.

TABLE 4

PERCENTAGE OF BLIGHTED TUBERS IN TRIALS AT 11 CENTRES, 1953

Upper figures : at lifting. Lower figures : after storage.

Centre	Cumb.	Dur.	Yorks	Ches.	Lincs	Cambs	Kent	Oxon	Wilts	Mon.	Devon
Variety	Maj.	Peak	Maj.	Peak	Glad.	K.E.	Maj.	Maj.	Maj.	Maj.	Banner
Treated	21.viii	21.ix	23.ix	9.ix	21.viii	19.viii	26.viii	12.ix	5.ix	25.viii	28.viii
Lifted	24.ix	9.x	14.x	2.x	1.x	4.ix	9.ix	28.ix	17.ix	9.ix	25.x
Soil cover	Good	Aver.	Aver.	Aver.	Good	Fair	Aver.	Good	Good	Good	Aver.
Soil type*	Sand	M.L.	M.L.	L.L.	M.L.	Fen	H.L.	M.L.	L.L.	H.L.	M.L.
Sulphuric acid	1·6	—	1·1	2·6	0·4	7·6	0·5	0·0	0·5	1·3	—
	1·6	—	1·7	3·7	0·4	7·6	2·8	0·0	0·5	4·0	—
Thiocyanate	1·3	—	0·0	6·5	5·6	10·0	1·2	0·0	0·5	0·9	10·2
(full strength)	3·1	—	0·0	12·8	6·0	12·6	1·2	0·0	4·0	2·1	29·5
Thiocyanate	—	—	1·1	8·0	2·7	—	0·9	0·0	0·5	0·4	17·5
(half strength)	—	—	1·1	8·6	2·7	—	1·8	0·0	5·0	1·9	30·5
Sodium arsenite	—	2·9	—	—	—	—	—	0·0	—	—	10·8
	—	2·9	—	—	—	—	—	0·0	—	—	17·5
Rotary hoe	—	1·1	0·0	1·7	0·0	12·9	0·5	—	0·0	—	9·1
	—	1·1	0·0	2·8	0·0	12·9	1·4	—	0·5	—	14·5
Rubber flail	—	—	—	—	—	10·1	0·4	—	—	1·0	—
	—	—	—	—	—	12·1	1·5	—	—	2·5	—
Horizontal cutter	—	—	—	—	1·4	—	0·4	—	—	—	—
	—	—	—	—	1·4	—	1·4	—	—	—	—
Cut by hand	3·6	—	—	—	—	—	—	—	—	—	—
	4·0	—	—	—	—	—	—	—	—	—	—
Control (untreated)	0·5	8·5	0·0	6·0	3·3	20·0	0·8	0·5	0·5	0·4	16·4
	1·5	9·0	0·0	8·7	3·7	20·0	0·8	2·5	3·2	1·7	43·0

* M.L. = medium loam ; H.L. = heavy loam ; L.L. = light loam.

GENERAL CONCLUSIONS FROM THE TRIALS

In point of efficiency and quickness in killing both potato haulm and weeds, sulphuric acid has been found to be the best of the chemical treatments. But sodium arsenite at high or low volume, and tar oil fractions such as TOF 54 at low volume, have been found to be good substitutes for acid, slower in effect but generally satisfactory. Both these materials have the advantage that they can be used in machines not specially constructed to resist acid ; but sodium arsenite has the disadvantage that it is poisonous. It must be handled and stored with care, and precautions must be taken to avoid drift on to neighbouring fruit, edible green crops or grass. It is also necessary to ensure the safe disposal of any material left in the empty drums or in the sprayer after use.

Ammonium thiocyanate liquors are potentially valuable haulm killers, with substantial advantages over sodium arsenite in that they are not poisonous, and over tar oil fractions in that they are not oily and are free from persistent phenolic smell. But progress with them must depend upon standardization of the products, as their composition is variable according to source, and constituents other than ammonium thiocyanate may be of consequence. Although they are by-products of gas works and tar distilleries, and are potentially available in quite large quantities, their economic future as haulm killers will depend upon cost of concentration and carriage.

Potato Haulm Killing Trials

For ware crops as grown in England and Wales, efficient mechanical haulm destruction appears to be as satisfactory a method as any, so far as the prevention of blight in the tubers is concerned, provided that lifting is deferred for at least 14 days after the operation.

Where the potato crop has to be lifted early, haulm destruction may prevent blight infection of tubers at lifting and therefore be of great importance. It may also be needed for limitation of tuber size in seed crops. But where, as in the great majority of ware crops in England and Wales, lifting is not begun until late September or October, and the haulm is then dead by natural causes, destruction of the haulm is more effective in clearing the ground for lifting and in the destruction of weeds than for preventing blight in the tubers.

The trials have shown that when, as is usual, haulm destruction is not done until blight is at the 25–75 per cent stage on the foliage, it is often too late to prevent more than at best about half of the infection from spores washing down to the tubers in the soil. If it is done earlier than the 75 per cent stage (where this is reached before mid-September), it may cause some loss of crop. For prevention of tuber infection in the soil, good soil cover, choice of variety not too susceptible to blight in the tubers, and preventive spraying to keep blight off the haulm as long as possible, may be of far greater importance than haulm destruction.

The Conferences of Crop Husbandry Officers and Plant Pathologists of the National Agricultural Advisory Service take this opportunity of thanking all the farmers who have given facilities for the carrying out of these trials on their crops; all the firms who have provided materials, or sent their machines and operators to take part in the work; and all the individual members of the N.A.A.S. who have participated in the arrangement of the trials and in the recording and reporting of results.

CARROT FLY INJURY AND "CANKER" OF PARSNIPS IN THE WEST MIDLANDS

by C. A. Collingwood* and H. E. Croxall†

National Agricultural Advisory Service, Evesham

Following heavy losses attributed to Parsnip Canker in the West Midlands in 1946, variety observation plots were laid down in 1947 and 1948 at a number of centres in the main parsnip-growing areas of Worcestershire, Warwickshire and Staffordshire. In the study of affected roots from these plots it soon became apparent that it was not possible to disassociate the rotting of a whole or part of the shoulders of the roots, referred to as "canker" throughout these observations, from injury caused by mining of the larvae of the Carrot fly, *Psila rosae*. F. This was in conformity with the observations of Ogilvie and Mulligan (1933,

* Now at N.A.A.S., Shardlow. † Now at N.A.A.S., Newcastle.

1934), who were of the opinion that much of the so-called " canker " of parsnips, especially in the Evesham area, was due to injury by dipterous larvae. On parsnips, Carrot fly injury occurs on the shoulder or side of the root near the top, and canker, if present, was almost invariably found to have developed at the site of this injury. The presence of even severe mining by Carrot fly larvae, however, did not always lead to rotting ; important factors conducive to the development of this rotting or canker were found to be wetness of the season and moisture-holding capacity of the soil, as indicated by soil type.

MEAN PERCENTAGE OF ROOTS SHOWING MINING BY CARROT FLY LARVAE, AND PARSNIP CANKER (ALL VARIETIES), 1947 AND 1948

Centre	Soil Type	1947 (Rainfall‡, Aug.-Oct. : 2·6 in.) Roots Mined by Larvae *per cent*	1947 Roots with Canker *per cent*	1948 (Rainfall‡, Aug.-Oct. : 9·8 in.) Roots Mined by Larvae *per cent*	1948 Roots with Canker *per cent*
Kidderminster ..	Sand	98·4	0·0	53·1	6·5
Evesham	Sandy loam	54·0	7·9	—	—
Whittington ..	Sandy loam	—	—	36·4	4·8
Ombersley ..	Light loam	76·6	0·0	79·0	30·0
Bournheath ..	Medium loam	84·1	15·8	71·0	47·9
Langwell Green ..	Medium loam	—	—	53·0	44·8
Welford	Heavy loam	—	—	62·5	41·7
Sedgeberrow ..	Silty clay	37·5	5·6	—	—
Weston-sub-edge ..	Clay	65·1	6·4	—	—
Long Marston ..	Clay	—	—	88·6	74·4
All centres ..		69·0	6·0	63·4	35·7

‡ At Worcester.

Carrot fly damage was extensive in both seasons and at all centres ; the incidence of canker was slight in the dry season (1947), heavy in the wet season (1948), and it varied considerably from centre to centre, the plots in the open sandy soil at Kidderminster being notably free. The observations were in line with those of Cotton (1918), who concluded that the prevalence of canker depended on seasonal conditions, and with those of Green and Hewlett (1950), who found that, at Wisley, canker was worse in the heavier than in the lighter soils.

Comparisons between varieties showed that there was no marked difference in susceptibility either to Carrot fly or to canker, except that varieties producing long thin roots, such as Magnum Bonum, were less affected than broad-shouldered, heavier-yielding varieties such as Offenham and Evesham. The mean percentages of roots cankered, according to variety, at all centres in the wet season 1948, were as follows :

Magnum Bonum	Hollow Crowned	Offenham	Systons Intermediate	Early Evesham
41·1	43·3	46·3	46·8	65·1

EXPERIMENTS ON CONTROL WITH BHC

The control of Carrot fly on carrots with BHC obtained by Newton, Satchell and Shaw (1946) suggested that it might be possible to determine whether the association of canker with Carrot fly damage was fortuitous. In 1947, small plots of parsnips were treated with 3·5 per cent BHC wireworm dust at 1 ounce

per 5 yards of drill, in mid-June, at the end of June, and in the second week in August. The control of Carrot fly was promising, but in this year little canker developed even in the untreated plots. In 1948 a single dusting was tried in late May, but this gave little or no control. In 1949, three out of six plots, each measuring 4 yards × 15 rows, at two centres, were dusted with 3·5 per cent BHC dust in May, June and August. Twenty-five roots per plot were examined for Carrot fly injury in October and for canker in December. The counts indicated a fair control of Carrot fly, with corresponding reduction of canker :

Centre, 1949	Treatment	Roots Mined by Larvae (October)	Roots with Canker (December)
		per cent	*per cent*
Brownheath ..	BHC dust ..	5·0	9·0
	Untreated ..	27·0	29·0
Pebworth ..	BHC dust ..	23·0	23·3
	Untreated ..	63·0	59·0

In 1952, larger plots sown in late March, 23 yards × 14 rows at Bournheath, and 15 yards × 14 rows at Littleton, were treated with the same 3·5 per cent BHC dust. At Bournheath there were three treatments—dusting on June 6 only, on July 30 only, and on both June 6 and July 30. At Pebworth two dustings were given, on May 17 and July 17. Samples of fifty roots in each plot were examined for Carrot fly injury in November and for canker in February :

Centre, 1952	Treatment	Roots Mined by Larvae (November)	Roots with Canker (February)	
			Total	Unmarketable
		per cent	*per cent*	*per cent*
Bournheath ..	BHC dust			
	June 6 and July 30	55	38	14
	July 30	50	44	20
	June 6	90	96	64
	Untreated control	91	91	72
Littleton	BHC dust			
	May 17 and July 17 ..	36	0	0
	Untreated control	91	0	0

At Littleton a fair control of Carrot fly was obtained but the site remained dry throughout the winter and no canker developed. At Bournheath the single application at the end of July was as effective as the two applications in June and July. At this centre first generation (June) attack was very severe, but only later Carrot fly damage occurring in August and September appeared to bear any relation to subsequent canker development. It was therefore decided to try only late treatments in 1953.

EXPERIMENTS ON CONTROL WITH DIELDRIN

Although no tainting of the roots had been detected following the use of BHC dust, it was thought that the risk of tainting might be avoided by the substitution of dieldrin, which had proved effective against dipterous larvae in pilot trials. At Littleton in 1953, dieldrin, at 1 ounce of 15 per cent emulsion in 2 gallons of water, was applied at the rate of 1 gallon per 75 yards of drill on August 18. The plots measured 3 yards × 10 rows, and there were four replications of treated and control. At Bournheath the solution was applied at the rate of 1 gallon per

50 yards of drill, in duplicated rows, each 200 yards long. Five random samples of ten roots were examined for each plot on October 14–15. Carrot fly damage was classified as " slight ", where there were less than three larval mines, " moderate " where up to one-half of the crown was mined, and " severe " where mining was more extensive. Canker was assessed as " slight " if less than half the crown showed rotting, and " severe " if more than half. The results were as follows :

Centre, 1953	Treatment	Mean Percentage of Roots with Larval Mining				Mean Percentage of Roots with Canker		
		Slight	*Moderate*	*Severe*	*Total*	*Slight*	*Severe*	*Total*
Littleton ..	Dieldrin ..	44·4	13·4	6·7	64·5	5·2	2·9	8·1
	Control ..	31·8	42·2	24·4	98·4	11·0	15·6	26·6
Bournheath ..	Dieldrin ..	28·0	12·0	0·0	40·0	2·0	0·0	2·0
	Control ..	13·0	60·0	27·0	100·0	13·0	5·0	18·0

The dieldrin treatment produced a substantial reduction in total percentage of roots injured by Carrot fly larvae, and even more considerable reduction in the numbers moderately and severely damaged. At Bournheath, 5 Carrot fly larvae were extracted from fifteen roots from treated plots, as compared with 95 from fifteen roots from untreated plots. Although by the lifting dates (October 14–15) canker probably had not reached its maximum development, there was a marked reduction in the treated plots as compared with the controls.

APPLICATION OF INSECTICIDES IN THE SEED DRILL

Small-scale experiments were made at the Evesham Laboratory to examine the possibility of controlling Carrot fly in parsnips by the application of insecticides in the drill with the seed. In 1952, six single-row plots 3 yards long were each treated with 1 ounce of 0·46 per cent gamma-BHC dust applied in the seed drill on May 16. The parsnips were lifted and examined in November. In 1953 similar plots were treated with ½ ounce of 1·5 per cent aldrin dust. The plots were sown on April 24 and the roots examined on October 14–15. The results for the two years are summarized below :

Year	Treatment	Roots Mined by Larvae	Roots with Canker
		per cent	*per cent*
1952 ..	Gamma-BHC ..	7·3	0·0
	Untreated control ..	78·2	0·0
1953 ..	Gamma-BHC ..	0·9	0·0
	Aldrin	11·2	0·5
	Untreated control ..	62·1	4·5

In both seasons a good control of Carrot fly was obtained, particularly with the gamma-BHC dust. No canker occurred in 1952, but even at the early lifting date in 1953 the amount of canker in the treated rows was considerably less than in the untreated controls.

DISCUSSION

Our experience from all the trials and observational work carried out during the years 1947–53 has been that control of Carrot fly, particularly in late summer, has been consistently accompanied by control of canker in the seasons and at the centres where canker occurred. The main factor favouring the development

of canker appeared to be high soil moisture, which is usually associated with heavy soil.

During the work, the parsnips were examined for wounds other than those caused by Carrot fly larvae. Horizontal growth cracks, such as those described by Cotton (1918) and Stirrup and Roebuck (1926), were rarely found, though splitting sometimes occurred at or shortly after lifting. On some plots substantial damage was caused by slugs and cutworms, but this was not associated with the subsequent development of canker. Stem eelworm infestation causing puffiness of the crown followed by rotting, as described by Walton (1936), occurred to some degree at three centres, but roots so affected were not included in the canker counts.

A number of fungi were isolated from the cankered roots. Species of *Phoma* and *Fusarium* occurred most frequently, but a wide range of others included *Botrytis cinerea*, *Penicillium* spp., *Mucor* spp. and *Verticillium dahliae*. Bacteria were almost invariably present in the more advanced cankers. No one organism or group of organisms was consistently associated with the cankers. This was in line with the observations of Stirrup and Roebuck (1926) that the cankers develop following fungal and bacterial invasion of wounds.

Wilkinson (1952), however, has stated that Parsnip Canker in America is due to infection by *Itersonilia* sp., while Jones (1953) has shown that one type of canker in England is caused by *Streptomyces scabies*. These divergent views may be due to the different isolation techniques used by different workers, but another possible explanation is that " canker " in parsnips is not a specific disease, but a condition that may arise from a number of differing causes.

We do not suggest that Carrot fly injury is the only cause of Parsnip Canker, but in the West Midlands it is undoubtedly an extremely important precursor of rotting that goes by that name, and its control can do much to reduce losses.

Thanks are due to the growers at each of the observation centres, to members of the West Midland N.A.A.S. horticultural staff, and to Mr. S. W. Rolfe and Mr. J. E. E. Jenkins for their co-operation and assistance in this work.

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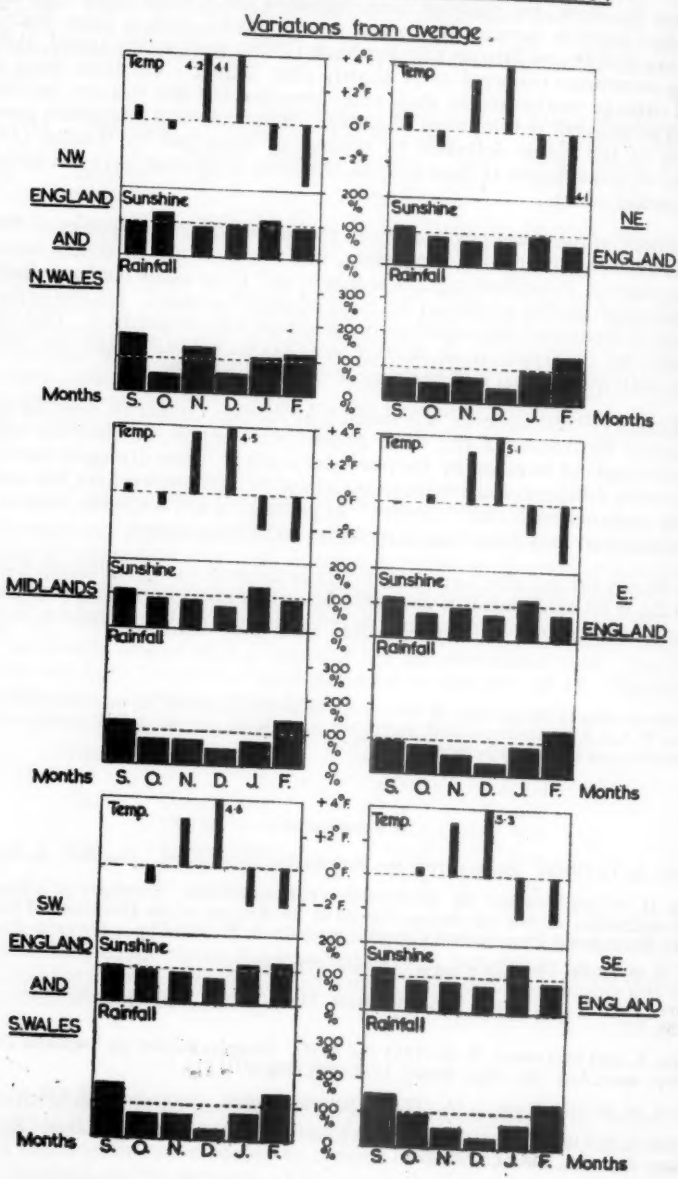
SEPTEMBER–FEBRUARY WEATHER 1953–54
Variations from average.
NW. ENGLAND AND N. WALES
NE. ENGLAND
MIDLANDS
E. ENGLAND
SW. ENGLAND AND S. WALES
SE. ENGLAND
Temp.
Sunshine
Rainfall
Months
S. O. N. D. J. F.
+4°F
+2°F
0°F
−2°F
200 %
100 %
0 %
300 %

THE WEATHER OF ENGLAND AND WALES*

AUTUMN AND WINTER, 1953–54

The weather of late autumn and early winter in 1953 was notable in that it was both mild and dry, an unusual combination at this time of the year, as most mild autumns have considerable rain. September was a mixed month, with a fine spell from the 5th to the 14th and high day temperatures around the 7th. A widespread gale occurred on the 21st and heavy rain fell locally in the last fortnight. October was a cloudy month, mainly dry, especially in the north ; it was much less windy than usual, quiet conditions prevailing over most of the country. November was unusually mild with less rain than average, except in the north-west. Very few low night minimum temperatures were experienced and frosts were infrequent.

The mild, dull and dry weather continued in December ; the high day temperatures during the period 2nd–4th were exceptional. Frosts were again infrequent, but there was a great deal of fog. For the first three weeks of January the weather was very changeable, with a severe gale on the 15th. From the 23rd onwards it was unusually cold ; temperatures remained at or below freezing point continuously at many places in England and Wales from the 26th to the 28th. There was considerable snow and sleet and towards the end of the month, with heavy snowfalls in places, chiefly in the Welsh Marches and in upland areas. This cold spell continued for the first week in February, and there were very low night temperatures ; 36 degrees of air frost were registered at Welshpool on the 2nd. The rest of the month was more changeable, with cold weather predominating ; snow was again fairly frequent and there were severe drifts in Kent.

The weather in each of the six months from September to February (inclusive) is represented graphically on page 104. Figures for the six districts of England and Wales are shown in terms of deviation from average for air temperature, sunshine and rainfall. The persistent dull dry weather of October, November and December in most areas is clearly shown. The temperatures of November and December were so far above average that the scale is insufficient to indicate the deviations in full, and the numerical value is shown beside the column.

NEW OR UNCOMMON PLANT DISEASES

Brand Canker on Rose Stocks. In January 1954, cankers were found on almost every stem on samples of briars newly imported into Scotland from the Netherlands and West Germany. Conidia of the *Coniothyrium fuckelii* type were produced on the Dutch briars. On the German material the cankers, from $\frac{1}{2}$ to 3 inches in length, occurred on blackened areas of bark and, in most cases, girdled the stem. Pycnidia on these cankers discharged conidia which measured 6–10 × 3–5μ. The fungus appears to be *C. wernsdorffiae* Laubert, the cause of Brand Canker, recorded on the Continent but not previously found in Britain.

ELIZABETH G. GRAY

* These notes, and the diagram on page 104, are provided by the Agricultural Branch of the Meteorological Office and published by permission of the Director.

***Ascochyta asteris* on China Aster.** Some asters (*Callistephus chinensis*) affected with a leaf spot, were received in September 1953 from a garden at Mildenhall, Suffolk. The spots were small, usually round, and light brown with a darker border ; similar, but canker-like, lesions occurred on the stems. A species of *Ascochyta* with pycnidiospores measuring 6–9 × 3μ was present on many of the lesions, both on the leaves and on the stems, and this was identified as *Ascochyta asteris* (Bres.) Gloyer. The fungus has not been recorded before in this country but it is recognized as a seedborne pathogen of asters in America (Gloyer, W. O., *Tech. Bull. N.Y. St. agric. Exp. Sta.*, 1931, **177**, 41 pp.) and has been found on germinating seeds in Denmark (Neergaard, P., *Aarsberetning fra J. E. Ohlsens Enkes Plantepatologiske Laboratorium, 1 April* 1939–31 *March* 1940, Copenhagen, p. 5).

I. F. STOREY AND F. JOAN MOORE

BULB SCALE MITE ON NARCISSUS

The Bulb Scale mite (*Tarsonemus laticeps* Halbert) caused considerable damage to narcissus bulbs in the early months of 1954. Reports received at the Plant Pathology Laboratory indicate that all the main bulb-growing areas were affected and that imported bulbs as well as English stocks were attacked. In Lincolnshire, where damage was particularly severe, the variety Verger seems to have been the most heavily infested, but other varieties were also damaged. In Hampshire large stocks of " Magnificence ", " Scarlet Elegance " and " King Alfred ", purchased from Jersey for forcing, were ruined, and four other varieties from the same source were also found to be infested. In Hampshire, too, some stocks of Spalding-grown bulbs were very seriously damaged. In Buckinghamshire, Dutch " Rembrandt " was severely damaged and, at Teignmouth, Devon the varieties " Rembrandt " and " Trevithian " were attacked.

The Bulb Scale mite is in some years a familiar and serious pest in forced bulbs where the conditions are ideal for rapid reproduction. In 1954, damage was also severe on some outdoor bulbs, and the mild weather in the last three months of 1953 is thought to be partly responsible for this. December was the mildest for twenty years and in most areas bulbs in the open had made considerable growth before the first cold weather started.

An infested bulb grown in the field may not show definite symptoms for several seasons and the grower will often attribute poor flowering to unfavourable growing conditions, but even a small number of mites are sufficient to cause a general loss of vigour. If, however, infested bulbs are forced, damage appears very quickly due to the rapid increase in the number of mites in the warm, moist conditions. This pest causes distortion of the leaves usually accompanied by a colour change to bright green with a yellow flecking. Accumulation of mites in the neck of the bulb damages the flower-bud and frequently the flower-stalk will continue to develop bearing a dead flower-bud at its tip.

Amaryllis (*Hippeastrum*) can also be attacked by this species. Red streaks and spots appear on the leaves and as growth proceeds the reddish lesions elongate and may eventually form a scar several inches long.

Plant Pest Survey

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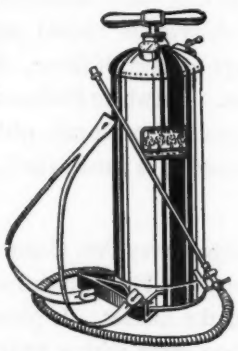

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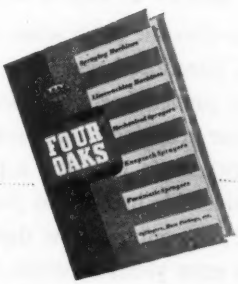

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PHENOXYLENE PLUS

and the economics of spraying

RECENT research by the Economics Branch of the Cambridge University School of Agriculture has proved conclusively that chemical weed control is one of the most profitable jobs that a farmer can do. These results were published last year in the Farmers' Bulletin No. 16, under the title "The Economics of Crop Spraying". The report takes into account the costs borne by the farmer when he decides to spray, including price of sprayer, maintenance and repair, labour and the cost of spray chemicals. It embodies the results of on-the-spot observation carried out under actual working conditions on a large number of farms, all under different degrees of weed infestation. Elsewhere Professor Blackman has reported that after three years' experiments with MCPA the yield of some barley fields increased by as much as 90%.

£18 worth of extra wheat for £1

Soon after the publication of the Cambridge survey Pest Control Ltd. introduced their new MCPA Phenoxylene Plus, which has since proved itself the most efficient on the market. It gives greater selectivity than any other hormone spray with a wider safety margin than any 2,4D preparation. There is also a very considerable increase in yield. The average results for farms all over the country show that for every £1 spent on Phenoxylene Plus extra yields of wheat worth £18 may be expected. Results very nearly as good have been obtained with oats and barley.

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